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EVALUATION OF POLYMERIC CLARIFICATION OF MEAT-PACKING AND DOMESTIC WASTEWATERS

Keith D. Larson, et al

Metropolitan Sewer Board

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16. Abstract

Laboratory tests were conducted to determine which system of chemicals would be most effective on ~~the~~ combined packinghouse and domestic waste. A dual system of chemicals was found which was effective in the treatment of this combined waste. This was a combination of ferric chloride and an anionic polyelectrolyte. This system was effective in forming a floc which would settle out under the dynamic conditions of the overloaded primary sedimentation tank. ~~It was demonstrated that~~ treatment with this system could effectively reduce suspended solids in the effluent of the primary sedimentation tank over what could be achieved without the use of this dual system. This was ~~accomplished~~ demonstrated by running: (1) a parallel system of identical test and control tanks and, (2) full plant scale investigation for both test and control periods, kept as identical as possible.

When full plant scale tests were run, laboratory data ~~was~~ were collected from various sampling points throughout the plant during the test and control periods. A significant reduction of BOD and suspended solids was obtained in the primary sedimentation tanks and a change in efficiency was not observed on the trickling filters resulting in an overall reduction in these parameters in the effluent from the secondary sedimentation tank. The cost of chemically treating the combined 10 mgd of wastewater would be approximately $45 per million gallons and would be less for strictly domestic wastes. (EPA)

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Evaluation of Polymeric Clarification of Meat-Packing and Domestic Wastewaters

by

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Program Element 1BB037

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ABSTRACT

The U.S. Environmental Protection Agency, the City of South St. Paul, and the Sewage Disposal Commission of South St. Paul (since October 1970 the Metropolitan Sewer Board) undertook a project to demonstrate the effectiveness of using organic and inorganic flocculating agents in the treatment of combined packinghouse and domestic wastes. The project was directed at not only a single system of flocculating agents, but at dual or multi-systems of organic and inorganic flocculating agents of wastewater.

A dual system of chemicals found effective in the treatment of this combined waste was ferric chloride and a combination of one of two organic polyelectrolytes, either Dow A-23 or Nalco 675. These two systems were effective in forming a floc large and dense enough to settle out under the dynamic condition of an overloaded primary sedimentation tank. Treatment with either of these dual systems effectively reduced suspended solids in the effluent of the primary sedimentation tank over that achieved without the use of these dual systems. This was demonstrated by running: (1) a parallel system of identical test and control primary tanks and, (2) a full-scale plant investigation for both test and control periods.

The primary flocculation of the collodial and fine particles by the ferric chloride produced a small volumnous floc. Secondary flocculation of the organic polyelectrolyte increased the floc size and density, producing a settleable precipitate. The ferric chloride alone was unsatisfactory, producing a non-settleable floc under prevailing hydraulic conditions.

Additional laboratory data were collected from various other sampling points throughout the plant during the test and control period when full-scale plant tests were run. Data were gathered on the effluent from the secondary settling tank following the trickling filters and on the effluent from the anaerobic stabilization pond which is the last stage of treatment. The overall results showed a leveling off of difference in removal achieved by chemical treatment between effluents from the trickling filters and the anaerobic pond.

The cost of chemically treating the combined 438 l/sec (10 mgd) of wastewater would be approximately $12 per million liters ($45 per million gallons). The economic breakdown of applying the dual system of inorganic and organic chemicals would be: 72% for chemicals, 15% for construction, 12% for labor, and 2% for utilities.

This report was submitted by the City of South St. Paul, Minnesota, Metropolitan Sewer Board, in fulfillment of Project No. 12130 EKK, which was partially sponsored by the U.S. Environmental Protection Agency. Work was completed as of July 1970.

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Acting as a biological consultant for the project were Dr. K. N. Knutson, Professor of Biology at the St. Cloud, Minnesota State College. He did a considerable amount of work studying the biota of the biological treatment process of the plant.

SECTION I

CONCLUSIONS

The use of chemical flocculation has been demonstrated in the treatment of combined 90 percent meat packing and 10 percent domestic wastes. Various chemical treatment schemes were demonstrated in an overloaded primary portion of the trickling filter plant at South St. Paul, Minnesota.

Of the various treatment schemes demonstrated, including an unsuccessful multichemical system using a patented process, a dual system of ferric chloride followed by a high molecular weight anionic organic polyelectrolyte proved to be the most effective. This combination of organic and inorganic polyelectrolytes in the primary portion of the plant reduced the suspended solids and BOD in combined packinghouse and domestic wastes by 56 mg/1 and 68 mg/1 respectively over the control period of one month, full scale operation without chemical addition. Suspended solids removal in this process was 255 mg/1 which resulted in a primary effluent of 101 mg/1. This is a 72 percent reduction as compared to 56 percent for the control period. Correspondingly, the BOD removal for this dual chemical system was 314 mg/1 and the primary effluent had a concentration of 269 mg/1. The efficiency of BOD removal was also greater, 54 percent compared to 29 percent for the control period.

Biological investigation of the biota of the trickling filters indicated that the chemicals did not have a detrimental effect on that treatment process. The suspended solids and BOD removal efficiency of the trickling filter remained unchanged from the control period to the test period. This resulted in a lower concentration of suspended solids and BOD in the effluent from the trickling filters. Test period results for suspended solids and BOD concentrations were 52 mg/1 and 66 mg/1 respectively while the control period showed 68 mg/1 and 107 mg/1 for the corresponding concentrations.

These tests demonstrated that a significant increase in reduction of suspended solids and BOD can be obtained by the use of a dual chemical system in the primary portions of the plant. Also demonstrated in the investigations was the value of correlative jar testing before field testing of flocculants. Laboratory jar testing was used to screen the various chemical treatment schemes to select the best for full plant operation. This approach proved to be valuable in the saving of time and money.

Based on a 438 l/sec (10 mgd) flow, the total cost of chemical treatment was $12 per million liters ($45 per million gallons). These costs were in addition to the normal operating costs of the existing treatment facilities. In a breakdown of the costs for full-scale utilization of the dual-chemical system of anhydrous ferric chloride and DOW A-23 or Nalco 675, 71 percent was required for chemicals, 15 percent for construction, 12 percent for labor, and 2 percent for utilities.

There were two additional benefits from the chemical treatment process. One was the reduction in chlorine demand from 13.9 mg/l to 5.5 mg/l. The other was that the overall phosphorus reduction for the plant was doubled. This left a 4.7 mg/l concentration in the secondary effluent for a 52 percent removal.

SECTION II
RECOMMENDATIONS

This study was made on a plant testing combined domestic and packinghouse wastes with primary treatment and secondary treatment consisting of trickling filters and an anaerobic stabilization pond. Tests were conducted on the effectiveness of various chemical systems in the primary portion of the plant and on the overall effect of the successful process through the biological portions of the plant.

If the process found to be successful at this plant is considered for other plants, additional tests should be conducted before the process is put into operation.

Further tests should be conducted to determine if chemical addition at a different point in the plant flow would be more effective. In the tests at South St. Paul, chemicals were added after the grit chambers and before primary sedimentation. Another possible point of addition could be after the trickling filters and before final sedimentation.

It would also be desirable to run tests to determine what effect these chemical systems have in plants having biological treatment other than trickling filters. The overall effect of this dual system of chemicals in an activated sludge plant might be different from that obtained in a trickling filter plant. A biological examination of the effects of these chemicals on activated sludge microorganisms would also be desirable.

Tests should also be conducted to determine if other plants experience a chlorine demand reduction with the use of chemical treatment. It is possible this effect was a result of the use of chemicals in conjunction with the treatment by the anaerobic stabilization pond at South St. Paul. If a reduction did occur at other plants using these systems of chemical treatment, a savings in cost of chlorine would result which would partially offset the cost of the chemicals.

Additional testing should be conducted to determine if the phosphate removal could be improved by introducing the chemicals at some other step in the treatment process other than in the primary clarifiers and also if the addition of lime along with the flocculant chemicals used would increase the phosphate removal.

SECTION III

INTRODUCTION

During 1940, South St. Paul, Minnesota, completed a 438 l/sec (10 mgd) high-rate trickling filter plant to treat combined domestic and meat packing waste. When the meat packers were operating the strength of the waste increased from 445,000 population equivalents per day in 1940 to 917,000 population equivalents per day in 1964. These figures were reduced to approximately 10 percent on weekends. During this period the efficiency of the plant dropped from 72 percent to 58 percent removal of biochemical oxygen demand (BOD).

In 1958, it became apparent that additional treatment would be required by both the adjacent Minneapolis-St. Paul Sanitary District Plant and South St. Paul Plant. The primary concern at that time was the low levels of dissolved oxygen in the Mississippi River during the late summer months.

Pilot plant studies conducted at South St. Paul indicated that the plant effluent BOD could be reduced by more than 50 percent by passing the effluent through an anaerobic pond of sufficient capacity to afford at least a five-day detention period. This addition was initiated in February, 1962.

During the three-year period, April 1, 1959 - March 31, 1962, the South St. Paul effluent had an average BOD of 464 mg/l during killing days. The State of Minnesota alllowed an effluent quality of 565 mg/l BOD which was anticipated as matching that of the Minneapolis St. Paul Sanitary District effluent when their new (then under bid) high-rate activated sludge plant was completed. The anaerobic pond reduced the BOD of the normal plant effluent by 66 percent, but this still left an effluent of approximately 150 mg/l, 2 1/2 times more than the 65 mg/l allowed. Consequently, the City of South St. Paul engaged an engineering firm to study the loads and capacity of the plant and to recommend a program to meet the maximum BOD allowed of 65 mg/l, and a method of sludge disposal other than lagooning.

Shortly after the engineering report was presented to the City an Upper Mississippi River Pollution Abatement Conference was held jointly by Wisconsin, Minnesota, and the U.S. Environmental Protection Agency (EPA). On completion of the conference the plant effluent limit of 65 mg/l BOD was lowered to 50 mg/l and subsequently lowered to 35 mg/l by the State of Minnesota.

In February 1965, the engineering firm developed several new plans encompassing second stage filtration and incineration costing approximately $10,000,000. The packing industries contracted an engineering firm to review this report which recommended treating hot packing plant wastes by the anaerobic contact process. The cost for the entire package again approached $10,000,000, a figure the industries found unacceptable.

The industries become interested in the possible efficiency and economy of chemical treatment of meat packing wastes. A review of the literature and existing patents indicated that the use of chemicals might reduce construction costs by $2,000,000. The City of South St. Paul made application to the EPA for a demonstration grant to determine the effectiveness of a chemical flocculation process on combined domestic and packing plant wastes, or on pure packing plant wastes. New grit chambers were necessary along with a new intercepting sewer from the industries and a new pumping station to separate the meat packing wastes. The increased costs of new grit chambers, chemical feed building, flashmixers, feed equipment, chemicals and personnel to undertake the demonstration were estimated at $845,000. EPA agreed to participate at 55 percent of the cost, not to exceed $450,000. The City of South St. Paul and the packing industries agreed to fund the remainder of the project cost.

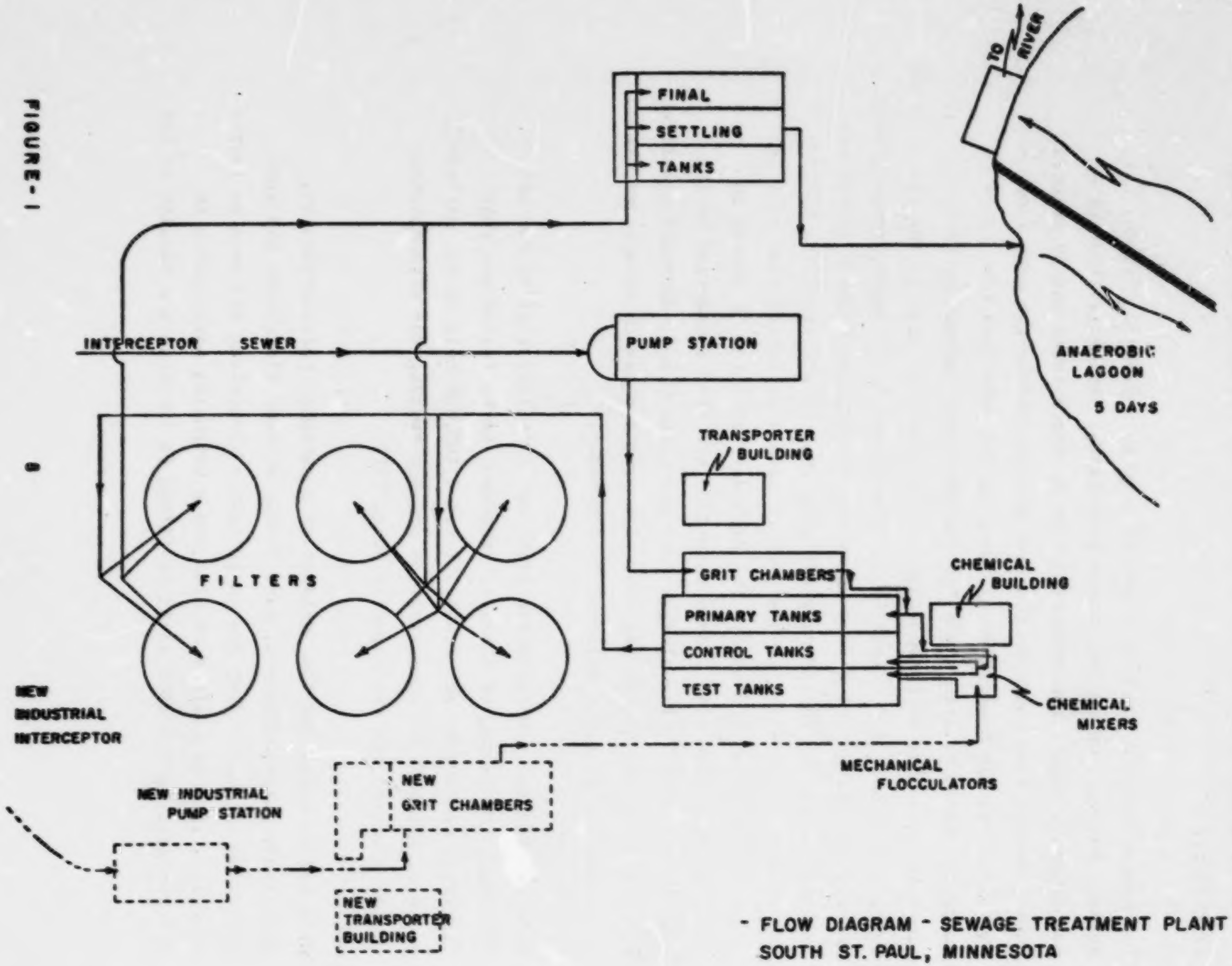
Even without the anaerobic stabilization pond, the South St. Paul Sewage Treatment Plant is not a conventional trickling filter plant (Figure 1.).

The sewage entered the plant, passed through a 2.54 cm (1-inch) bar screen, and was pumped into three grit tanks. At design flow of 438 l/sec (10 mgd) the detention time in these tanks was 30 minutes. During the killing hours at the meat packing plants the peak flow was 876 l/sec (20 mgd), thereby reducing the detention time by 50 percent. From the grit tanks the sewage flowed through mechanical flocculators. The detention time at 438 l/sec (10 mgd) in the flocculation tanks and primary clarifiers is 45 minutes and 1 1/2 hours, respectively. Between the mechanical flocculators and rectangular primary clarifiers is a baffle wall. The primary effluent goes to six trickling filters and then to the final clarifiers which have a detention time of 1 1/2 hours at 438 l/sec (10 mgd). The secondary effluent is pumped to the anaerobic pond with 5 days detention and then discharged to the Mississippi River. The sludges from the primary and secondary clarifiers are pumped to the sludge lagoons. The grit and paunch manure are stored in a diked earth basin adjacent to the plant.

When the Federal demonstration grant was initially applied for and received, the system of chemical treatment to be tested was that described in Patents No. 2,434,321 and 3,142,638 held by Mr. Blaisdell and Mrs. Klaas. The demonstration project testing the effectiveness of polyelectrolytes was begun in June, 1967.

This system calls for the addition of a cationic polyelectrolyte, an anionic polyelectrolyte, some finely divided flocculant aid such as sodium bentonite clay and an inorganic flocculant aid such as ferric chloride, ferrous sulfate or alum and a weighting agent which is incorporated in the floc as it is formed to increase the density of the

FIGURE-1



- FLOW DIAGRAM - SEWAGE TREATMENT PLANT
SOUTH ST. PAUL, MINNESOTA

floc and cause it to settle more rapidly. As described by the patent holders, the anionic polyelectrolyte is added with the bentonite and the cationic polyelectrolyte is added with the ferric chloride and iron ore. These two additions may be in series to one stream of wastewater which are consequently mixed together.

Theoretically, the ferric chloride and cationic polyelectrolyte would form a floc with the wastewater. The bentonite with a small quantity of anionic poielectrolyte mixing in it would also form a floc with the wastewater. These two streams of wastewater would be combined and the two oppositely-charged flocs would form a larger floc which would immesh the iron ore, increasing the density of the floc, causing it to settle. The patent also provided for variation in order of addition of this multiple system of chemicals.

Tests were run for several months using this Blaisdell-Klass process. The process was ineffective on the wastewater at the South St. Paul plant, even though it had reportedly been effective at other plants.

Several other systems were then tried under the instruction and supervision of personnel from the Robert S. Kerr Environmental Research Laboratory at Ada, Oklahoma. Those systems tried were a single system of chemicals using only an anionic polyelectrolyte, and a dual system using ferric chloride followed by an anionic polyelectroyle.

The ferric chloride provided the trivalent ferric ion which was adsorbed by colloidal particles, neutralizing the surface charge and allowing them to coalesce into larger particles. This would result in a floc too fine to settle out but which could be further coalesced into a larger heavier floc by the addition of an organic polyelectrolyte.

Two different polyelectrolytes were found effective in laboratory tests and these were subsequently tested on a plant scale. A series was also run using ferric chloride only. This was done to see how great an effect the polyelectrolyte was having, and also to see how much reduction could be obtained from the ferric chloride.

Tests were run on industrial packing house wastes, domestic waste, and a combination of these two. The domestic waste contained stockyards waste and packing plant wastes from two small slaughtering houses and therefore, cannot be considered typical domestic wastes. These tests using the dual system were run on a flow of wastewater which had been split between two primary sedimentation tanks. The flow to one tank was treated with chemicals while the second tank was used as a control. Excess flow which was not treated was bypassed to a third sedimentation tank. Finally, a test was run treating the whole plant flow with that system which was found to be most effective. This was done to determine what the overall effect on the plant effluent would be after the treated wastewater was passed through the trickling filters and anaerobic stabilization pond. Since at the time this test was conducted the stabilization pond had a seven day detention period, due to discontinuing of slaughtering at Swift and Co. (one of the two larger packing plants), it was decided that a minimum test period of one month would be required to determine what overall effect the addition of chemicals would have on the plant effluent. This one month test was preceded by one month during which the plant was operated in the same manner that it would be during the test period except flocculating chemicals were not added with the same parameters being examined in the laboratory.

SECTION IV

DESIGN AND CONSTRUCTION

The chemical mixing chambers were designed for addition of chemicals either in series or in parallel. An arrangement of splitter boxes was constructed ahead of the mixing chambers to allow the wastewater being tested to be split, half being passed through mixing chambers and a parshall flume meter into a settling tank, while the other half was passed through a parshall fume meter into a second settling tank with no chemicals added. That portion of the wastewater to which chemicals were added was first split between two small mixing chambers and then recombined in one large mixing chamber before it passed through the parshall flume meter.

A new interceptor sewer was contructed as part of the plant expansion which allowed meat packing plant industrial wastewater to enter the plant separately from domestic wastewater. New grit chambers and outside piping were constructed to allow this separation to be maintained to the chemical mixing chambers. These grit chambers are not conventional grit removal units, they more properly could be described as preprimary and grit removal units since the detention times varied from 15 to 60 minutes, depending on the rate of flow and number of units in use. This allowed for testing of chemicals on either industrial or domestic wastewater or a mixture of the two. Two 122 cm (48") lines carried the wastewater from the grit chambers to the chemical mixing chambers. At the influent to the chemical chambers a series of gates were constructed to allow selection of flow from either line and bypassing of flow from the other line to the third settling tank. The gates allowed for equalization of flow between the test and control tank.

Figure 2 shows the chemical mixing system. The plant flow diagram before completion of the construction project is shown in Figures 3 and 4 and the flow diagram after completion of the new facilities is shown in Figure 5.

DIVISION SYSTEM AND FLASH MIXERS

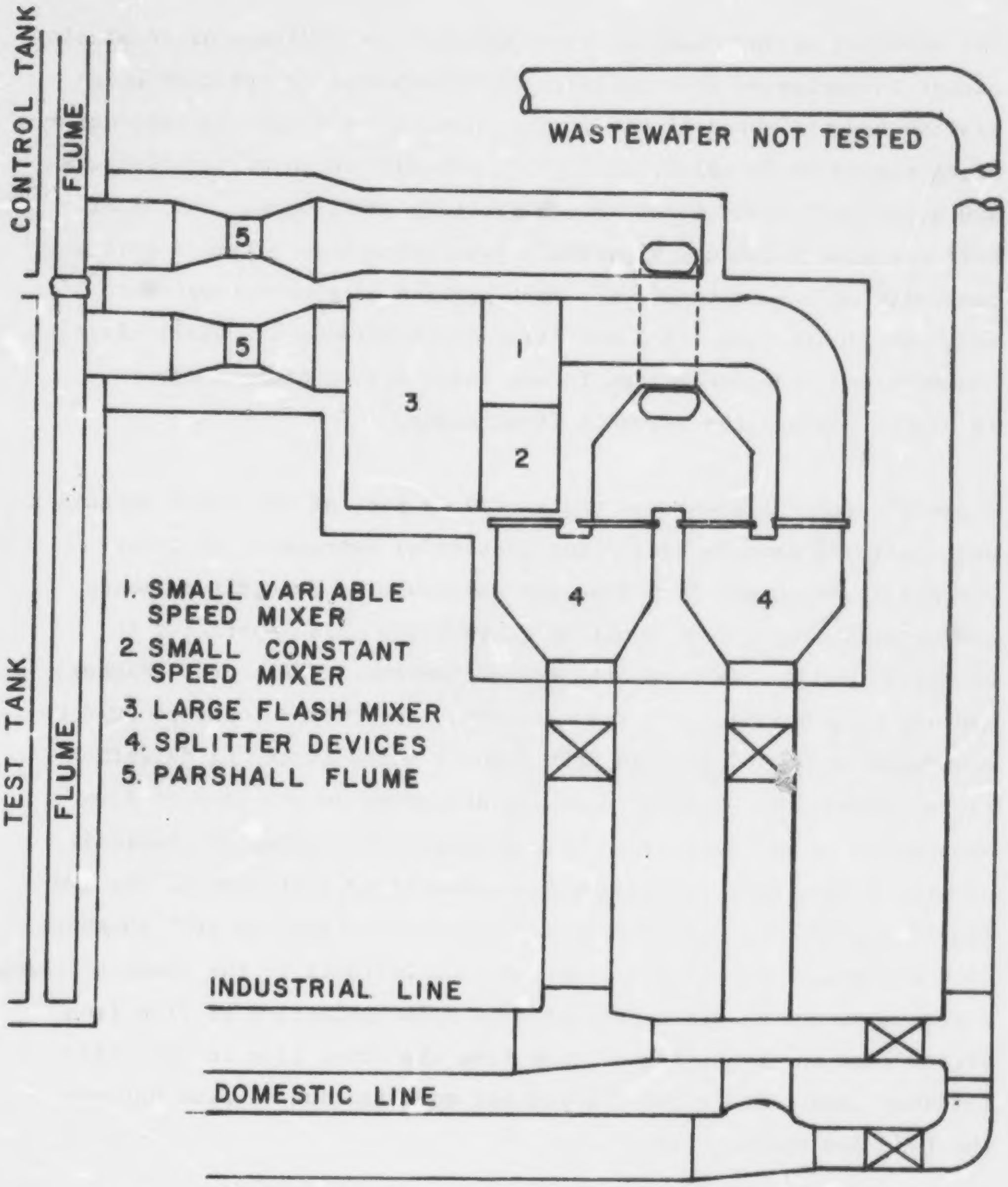
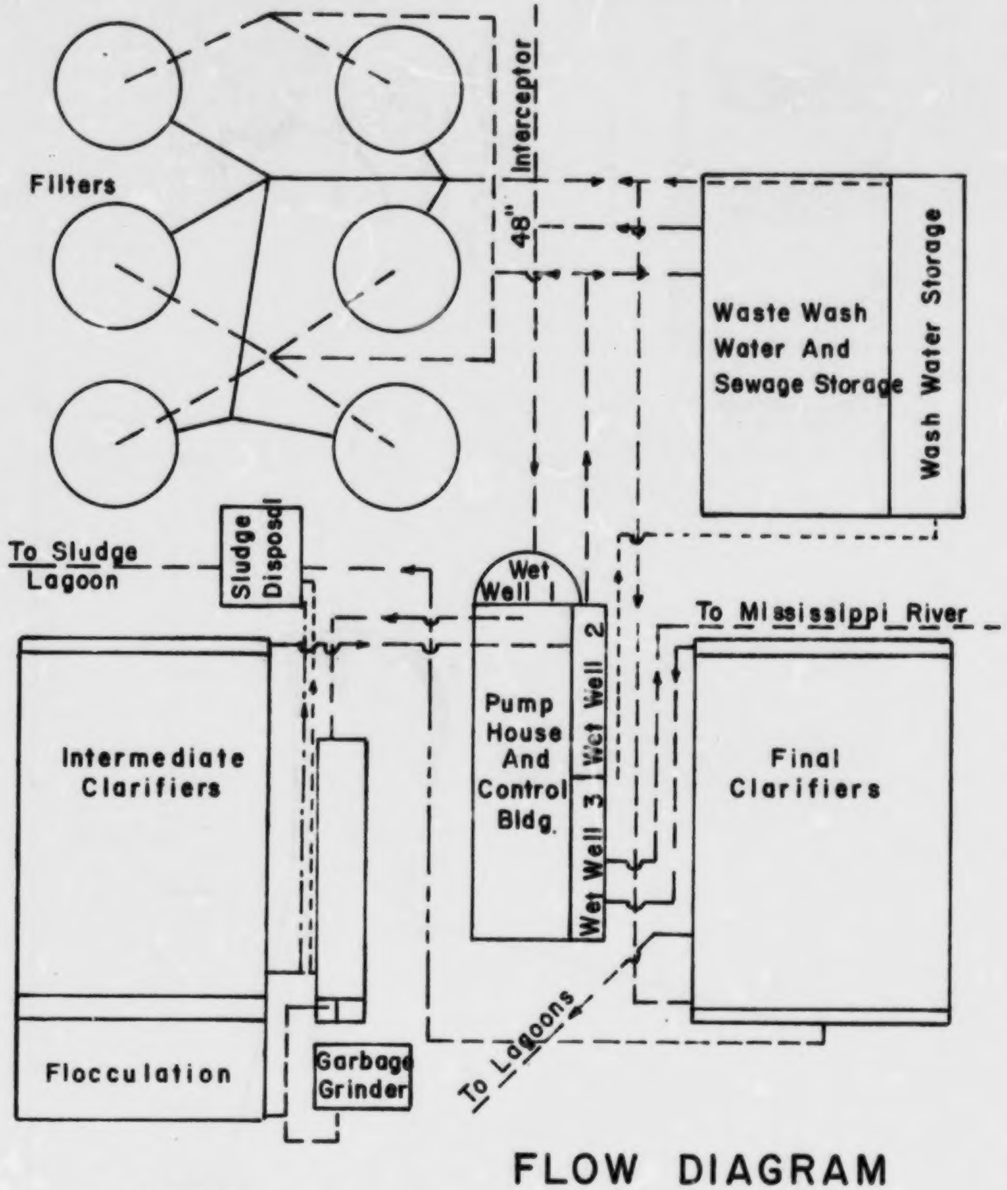


FIGURE-2



FLOW DIAGRAM
Sewage Treatment
Plant
South St. Paul, Minn.

FIGURE— 3

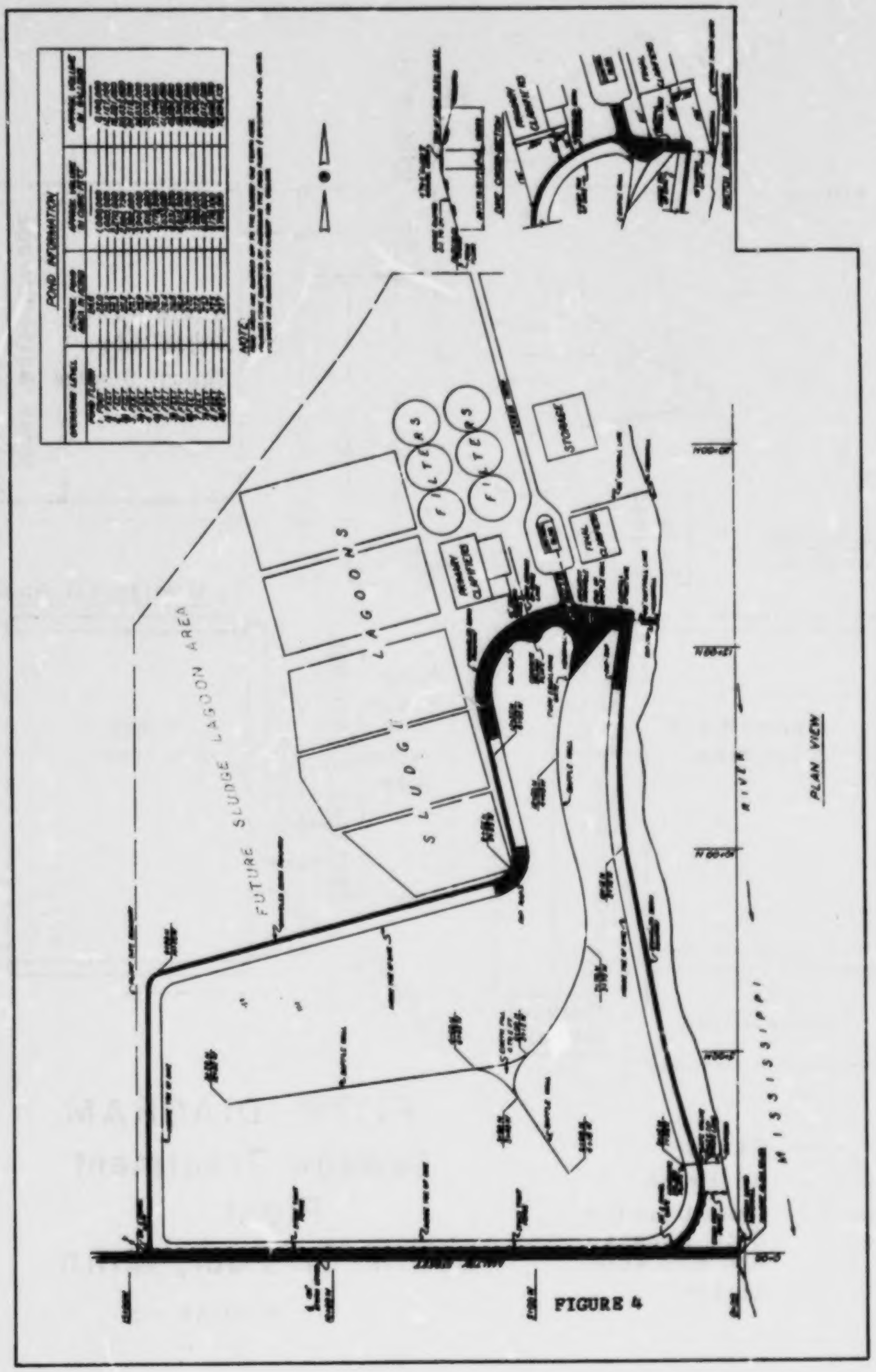
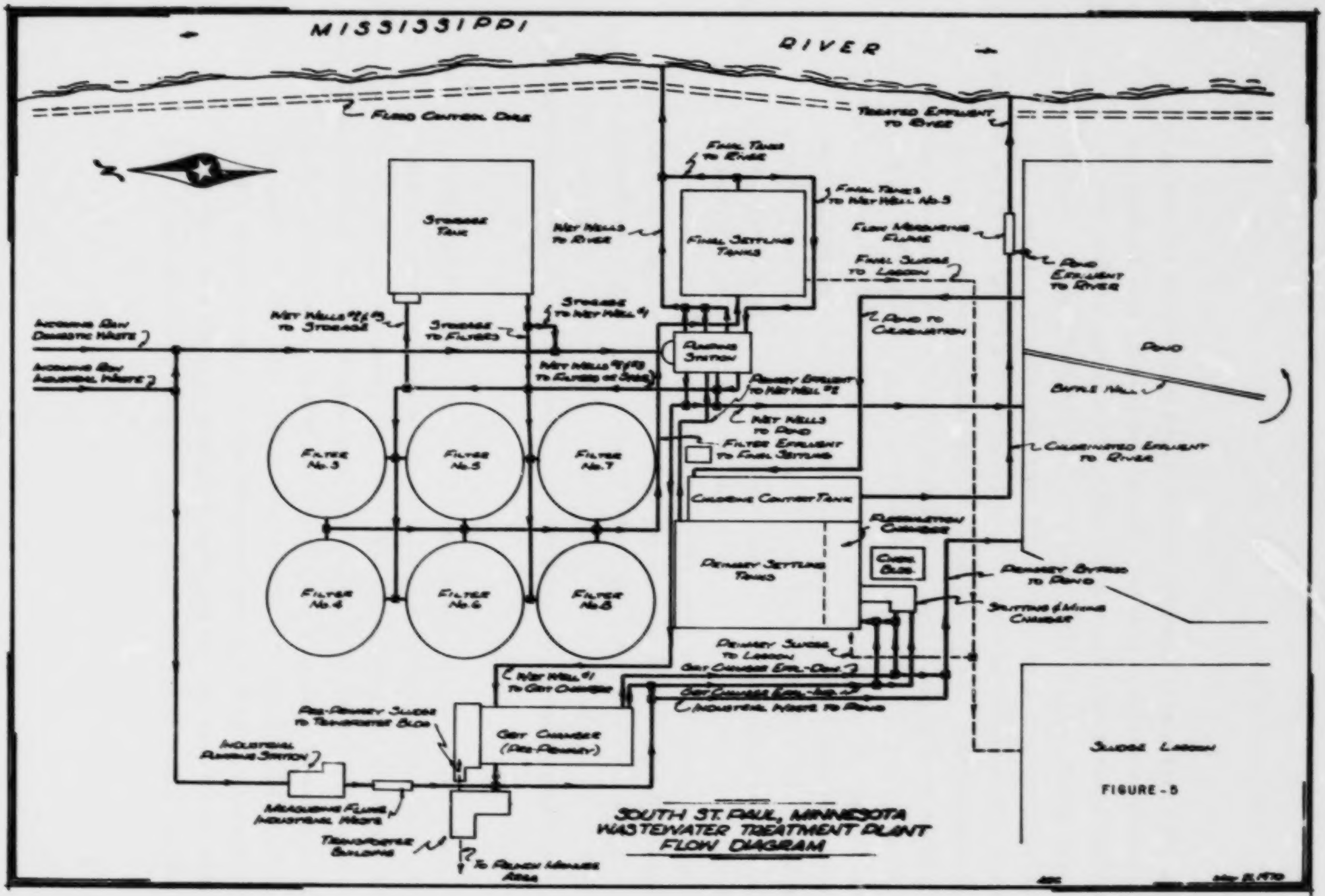

POND INFORMATION
FUTURE SLUDGE LAGOON AREA
SLUDGE LAGOONS
FILTERS
FILTERS
STORAGE
PRIMARY CLARIFIERS
FINAL CLARIFIER
MISSISSIPPI RIVER
PLAN VIEW

FIGURE 4



SOUTH ST. PAUL, MINNESOTA
WASTEWATER TREATMENT PLANT
FLOW DIAGRAM

FIGURE - 5

The two small mixing chambers were equipped with wooden baffles which forced the wastewater flow to enter at the bottom, flow through the mixing chambers, and leave at the top. Each mixing chamber was provided with a flash mixer unit. One of the small mixing chambers was equipped with a constant speed mixer driven by a 1.12 Kw (1 1/2 hp) motor. This was to be used for the addition of bentonite and the anionic polyelectrolyte. The second small mixing chamber was equipped with a variable speed mixer driven by a 2.24 Kw (3 hp) motor. It was initially planned to add the cationic polyelectrolyte, ferric chloride, and iron ore to this mixer. The variable speed provided for adjustment to the speed necessary to keep the iron ore in suspension. After the flow of wastewater passed over the baffle and out of the two small mixing chambers it passed into the large mixing chamber. This chamber was equipped with a float and a mechanical liniarizer which indicated flow as a percent of maximum flow. From the parshall flume the flow passed into the test sedimentation tank. The half of the flow used for a control passed from the splitter boxes through a flume leading directly to a Parshall flume meter identical to the one following the mixing chambers. From the meter it passed into the control sedimentation tank.

In addition, a building was constructed to house the tanks used for preparing chemical solutions, the proportioning pumps used to feed the chemicals and provide storage space for chemicals. Four mixing tanks of 1890 liter (500 gallon) capacity were installed, two for the cationic combination of chemicals and two for the anionic combination. This allowed continuation of chemical feed while a new tank of chemicals was prepared. Each tank was equipped with a chemical mixer. The tanks to be used for the cationic chemicals were also to have the iron ore mixed in and were mixed with chemical mixers having 2.24 Kw

(3 hp) motors. The tanks to be used for mixing the anionic chemicals were equipped with chemical mixers having .75 kw (1 hp) motors. A plastic impellor on the tanks mixing the cationic chemicals was necessary because of the corrosiveness of ferric chloride. The impellor and shaft was further covered with fiberglass to protect the shaft and set screws from the strong ferric chloride solution. A chemical proportioning pump was provided for both the anionic and cationic chemicals. These pumps were driven by a variable speed DC motor controlled by a rheostat.

A small laboratory for on-the-spot tests was incorporated into the new building. This was in addition to the existing, larger, well-equipped laboratory in the main pumping station. Some additional facilties were also built during the expansion which were not directly related to the demonstration but aided in conducting experiments. These included:

1. A new industrial pumping station equipped with automatic bar screen and pumps of sufficient capacity to pump the wastewater coming to the plant through the new industrial interceptor.

2. A new ejector building to handle the paunch manure coming into the plant and removed in the grit chambers (which are really more of a preprimary tank than a grit chamber). Paunch manure is a fibrous material which cannot be pumped and it is therefore necessary to transport it to the sludge lagoons for disposal by an air ejection system.

3. New chlorination equipment was installed in the old ejector building and the old grit chambers were converted to chlorine contact tanks.

4. New distributor arms were installed on the trickling filters. The original arms were quite old and of the two-arm type. These were replaced by four-arm distributors to provide more even distribution of water on the filters.

5. New pumps were installed in the main pumping station to provide greater capacity to the filters and the pond, and to provide reciculation of plant effluent onto the filters.

SECTION V

EXPERIMENTAL PHASE

Shortly after the project got underway, laboratory evaluation of the chemical treatment system in the Blaisdell and Klaas patents was begun. Early in the project a cost limitation of about $2.60 per million liter ($10 per million gallon) was set for chemical costs. Screenings were made of a number of different polyelectrolytes used in the Blaisdell and Klaas method. A number of combinations of chemicals which produced a fair increase in settleable solids were uneconomical. Different types of bentonite and iron ore were also tested to determine which was more effective when used in the Blaisdell and Klaas system.

Laboratory evaluations were conducted with a six-gang floc stirrer. One liter of waste was used with each stirrer. The desired chemicals or combination of chemicals were added to the beaker of wastewater while it was stirred at 145 rpm. The stirring rate was increased to 100 rpm for a 15 second period to insure complete mixing and then reduced to 15 rpm for five minutes. The waste was placed in an Imhoff cone and allowed to settle for thirty minutes after which a sample was drawn off the top.

BOD and suspended solids were run on this sample.

Initially, a number of tests were run using visual inspection only to determine the most effective combinations of chemicals. In these, the polyelectrolytes recommended by the patent holders were used, but variations were made in the concentration of the chemicals and the order of addition. The polyelectrolytes recommended by the patent holders were National Starch Floc Aid 1038 as a cationic polyelectrolyte and Monsanto's Stymer-S as an anionic polyelectrolyte. Flocculation aids were sodium bentonite and anhydrous ferric chloride. The weighting agent was hematite iron ore tailings. Also, some inorganic chemicals other than ferric chloride were tried. The results of these initial tests are shown in Table 1.

At no time was a large heavy floc produced from any combination of chemicals. However, some did show a fine floc and a marked increase in settleable solids when allowed to settle in in an Imhoff cone. The patent holders had suggested a combination of chemicals as follows: The bentonite was to be added at a dosage of 3 to 6 mg/l and the anionic polyelectrolyte at 1/2000 the dosage of bentonite. The other chemicals would be added together in a 1:2:3 ratio of cationic polyelectrolyte to iron ore to ferric chloride. the total dosage of these cationic chemicals was to be 3 to 6 mg/l. This combination of chemicals did not prove particularly effective. It was necessary to greatly increase the dosage to get an observable increase in settleable solids in the Imhoff cones which resulted in too great a cost of chemicals. It was found that by increasing the dosage of bentonite to 120 mg/l and keeping the rest of the chemicals at the lower concentrations, an observable increase was made in settleable solids while a cost of $3.23 per million liters ($12.20 per million gallons) was also obtained as indicated in Table 2.

It must be concluded that the chemical dosages recommended by the patent holders did not flocculate packing plant wastes in laboratory tests. It is questionable if the mechanism by which BOD reduction occurred at higher dosages of bentonite was the result of flocculation or adsorption. It was later discovered, however, that this higher degree of bentonite was not effective in plant-scale tests. This was possibly due to the higher concentration (8% suspension) at which the bentonite had to be prepared when used in plant-scale quantities due to mechanical

Table 1

Preliminary Work*
Laboratory Screenings

Anionic mg/l	Cationic mg/l	Settleable Solids Blank ml/l**	Settleable Solids Sample ml/l	$/MG Cost
3	6	13.5	13.0	--
12	24	14.8	14.2	--
1.5	3	15.5	15.0	--
60	120	13.5	40.2	--
60	30	13.0	16.0	--
30	15	13.0	15.0	--
120	30	13.0	20.0	--
120	60	13.0	23.0	--
60@1/40 Sty-S"	30	21.0	28.0	--
60@1/40 Sty-S	60	21.0	30.0	--
6	6	5.0	5.0	--
12	12	5.0	5.0	--
18	18	5.0	6.5	--
12	12+12 mg/l lime	5.0	6.5	--
30	30	5.0	5.5	--
45	45	5.0	7.5	--
30	30+30 mg/l lime	5.0	7.5	--
60	60	5.0	10.0	$48.50
60	60 using PEI instead of starch	5.0	36.0	--
60	60+100 mg/l lime	5.0	43.0	--
30	30+25 mg/l lime	5.0	7.0	--

Table 1 (continued)

Anionic mg/l	Cationic mg/l	Settleable Solids Blank ml/l**	Settleable Solids Sample ml/l	$/MG Cost
30	30+50 mg/l lime	5.0	8.0	$28.12
30	30+75 mg/l lime	5.0	10.5	35.75
30	30	7.2	9.5	--
30	30 PEI instead of starch	7.2	15.0	57.60
30	30 PEI instead of starch +50 lime	7.2	18.0	65.30
30	30 PEI instead of starch +50 alum	7.2	26.0	166.60
30	30 PEI instead of starch +50 alum	7.2	12.0	133.20
30	5 PEI (alone)	7.2	9.5	--
30	5 PEI +50 mg/l lime	7.2	10.0	--
30	5 PEI (alone)	7.2	16.0	120.70
60	30	7.2	13.0	26.70
90	30	7.2	16.5	29.20
120	30	7.2	30.0	31.70
150	30	7.2	46.0	34.20
90	30 PEI-no starch +50 mg/l alum	7.2	47.0	205.80
90	30 PEI instead of starch	7.2	38.0	62.60
30	30	19.0	25.0	--
60	30 PEI instead of starch +25 mg/l alum	19.0	29.0	--
60	15 PEI instead of starch + 25 alum	19.0	31.0	87.05

Table 1 (continued)

Anionic mg/l	Cationic mg/l	Settleable Solids Blank ml/l**	Settleable Solids Sample ml/l	$/MG Cost
60	15 PEI-no starch +50 mg/l alum	19.0	36.0	146.55
90	15 PEI-no starch +50 mg/l alum	19.0	43.0	149.05
60	10 PEI-no starch +25 mg/l alum	19.0	30.0	80.30
90	10 PEI instead of starch +25 mg/l alum	19.0	36.0	82.80
30	15 PEI instead of starch +25 mg/l alum	19.0	25.0	--
60	15 PEI instead of starch +25 mg/l alum	19.0	31.0	70.35
90	15 PEI instead of starch +25 mg/l alum	19.0	38.0	72.85
90	15	19.0	27.5	--
90	15	4.5	6.1	18.35
60	15+15 mg/l lime	4.5	5.8	18.16
30	15+30 mg/l lime	4.5	5.3	17.97
0	15+15 mg/l lime	4.5	6.2	17.78
120	15	4.5	10.2	20.85
60	15 +45 mg/l lime	4.5	6.2	22.78
150	0	16.8	35.0	12.50
210	0	16.8	57.0	17.50
120	0	16.8	28.0	10.00
120	6	19.0	29.0	14.34
150	6	19.0	43.0	16.84
180	6	19.0	52.0	19.34

Table 1 (continued)

Anionic mg/l	Cationic mg/l	Settleable Solids Blank ml/l**	Settleable Solids Sample ml/l	$/MG Cost
180	3	19.0	50.0	17.17
180	0	19.0	50.0	15.00
210	3	19.0	63.0	19.67
150	3	19.0	37.5	14.67
120	3	19.4	24.0	12.17
90	3	19.0	25.5	9.67
150	1.5	19.0	40.0	13.59
120	1.5	19.0	31.0	11.09
30	30 +50 mg/l alum	8.5	26.0	--

Lime - $Ca(OH)_2$ A.R.
P.E.I. - Polyethylene Imine
Starch - National Starch Floc Aid 1038
Alum - $Al_2(SO_4)_3$ A.R.

---

* All anionic was bentonite with 1/2000 Stymer-S, and all cationic was at the ratio of 1:2:3 National Starch (Hot Water), Hematite, $FeCl_3$.

** By blank is meant sample stirred and settled the same time as the test sample but without addition of chemicals.

" Stymer-S

Table 2

Blaisdell and Klaas Method
(Average of 5 trials each)

Sample No.	Anionic	Cationic	Cost/MG	Set* Solids	Sus* Solids	Percent Reduction	BOD	Percent Reduction
1	Blank**	--	--	--	1138	---	1930	---
2	Control***	--	--	14.5	508	55.2	1326	30.9
3	60	3	7.17	15.0	510	55.1	1178	39.1
4	120	3	12.17	26.1	394	65.3	967	49.3
5	120	0	10.00	28.0	--	--	--	---
6	150	3	14.67	37.4	336	70.4	812	58.0
7	120	3+10 alum	16.13	30.8	--	--	--	---
8	150	0	12.50	31.8	--	--	--	---
BOD	$S_2=\pm325$	$S_4=\pm258$	$t_{2,4}=2.59$	$P_{2,4}=0.05$				

* Settleable - Suspended Solids
** Blank - Sample As Taken
***Control - Stirred & Settled

limitations of the mixing equipment. In this higher concentration the particles of bentonite were not as well dispersed in the water. Also, the floc formed in the laboratory was a fine floc and was settled under static conditions in the sedimentation tanks. The dosage of chemicals arrived at for further polymer screenings and initial plant-sclae tests was 120 mg/l of bentonite, 120/2000 mg/l of Stymer-S, 1.5 mg/l of ferric chloride, 1.0 mg/l of iron ore, and .5 mg/l of National Starch Floc Aid 1038. (A summary of the screening results are shown in Table 2). A BOD was run on some samples of wastewater treated with the above concentrations of chemicals and a BOD reduction of 350 mg/l was obtained.

Later when more extensive laboratory testing was done, it was found the same results in BOD reduction could be obtained if polyelectrolytes were left out and the sample of wastewater was treated just with bentonite, ferric chloride and iron ore. This was concluded from an average of ten trails on which suspended solids and BOD's were run. See Table 3. Increasing the concentration of the polyelectrolytes did not reduce BOD more than when bentonite was used with no other additives. At 180 mg/l of bentonite, however, a greater BOD reduction was observed. See Table 4. A number of laboratory tests indicated this BOD reduction to be in the order of 250 mg/l. Technical personnel of the American Colloid Company indicated that the actual mechanism by which this reduction occuppied was one of adsorption of dissolved material on the bentonite with subsequent flocculation of the bentonite by ferric chloride or other ions.

A number of polyelectrolytes were screened. A total of 50 polyelectrolytes from 16 manufacturers were checked. No great difference in effectiveness was found in any of these polyelectrolytes at the concentration tested. However, some did appear to be slightly more effective than others. Of these, 12 were selected

Table 3

Polyelectrolytes Giving Best Results In Lab Tests
Blaisdell And Klaas Process
Anionic Polyelectrolytes - Average Of Ten Trials

Polyelectrolyte	Cost $/MG	Sus. Solids mg/1	% Red.	Total Solids mg/1	% Red.	BOD mg/1	% Red.
Unsettled Sample	--	796	-	2837	18.2	1440	-
Blank Sample	--	309	61.2	2318	23.4	940	34.6
Blaisdell & Klaas	12.20	232	70.8	2173	24.0	682	52.7
Bentonite & Ferric Chloride with Iron Ore	11.25	240	69.4	2158	23.1	698	51.5
Rohm & Haas A10	13.14	238	70.1	2189	22.8	728	49.4
Nalco's 675	--	260	67.3	2180	23.1	735	49.0
Goodyear's 708	13.21	265	66.7	2194	32.6	705	51.0
Cationic Polyelectrolytes - Average Of Ten Trials							
Unsettled Sample	--	943	-	2939	-	1562	-
Blank Sample	--	352	62.3	2307	21.4	1079	30.9
Blaisdell & Klaas	12.20	295	68.6	2156	26.7	809	48.3
Gen Mills Genfloc 263	--	253	73.2	2134	27.4	772	50.6
Gen Mills Gendrive 162	14.20	226	76.0	2109	28.2	758	51.6
Nalco's D-2073	--	264	72.0	2133	27.4	787	49.7
Garratt-Callahan's #78	--	292	69.0	2145	27.0	768	50.9

Table 4

Effects of Variations of Polyelectrolytes and Bentonite in Laboratory Tests

Sample	BOD	% Reduction
Untreated	1923	--
Control	1286	33.0
Blaisdell & Klaas[2]	962	50.0
Hercules 220 at .5 mg/l[3]	913	52.5
Hercules 220 at 1.0 mg/l[3]	914	52.4
National Starch 1063 at 0.5 mg/l[3]	912	52.6
Bentonite only at 180 mg/l[4]	745	61.1

1. Stirred with no chemicals
2. 120 mg/l bentonite, 120/2000 mg/l Stymer-S, 0.5 mg/l starch 1038, 1.0 mg/l iron ore, 1.5 mg/l ferric chloride
3. Same as 2 except for polyelectrolyte at indicated dosage
4. Bentonite at 180 mg/l, no other additives

for more extensive testing. The results of these tests are indicated in Table 5 and Figure 6. Those polyelectrolytes which it was felt might be tested on a plant-scale are indicated with an asterisk. The results indicated are an average of 8 to 10 trails for each polyelectrolyte. A control sample and a sample using the polyelectrolytes recommended by the patent holders were carried along with each trial.

A number of tests were also run on bentonite to determine whether calcium or sodium bentonite would be most effective and to determine the best way to add it. The patent holders indicated that sodium bentonite was the most effective. A sample of calcium bentonite (Panther Creek bentonite) was obtained and tests were made using 60 and 120 mg/l of calcium bentonite and 60 and 120 mg/l of sodium bentonite. The results are indicated in Table 6. The calcium bentonite showed very little increased efficiency in BOD reduction while the sodium bentonite showed the same effect obtained in previous tests.

A form of sodium bentonite with the brand name of KWK bentonite was also tested. This bentonite has larger particles of about 40 mesh and makes preparation of suspensions less difficult. The bentonite used formerly was a powder of 200 mesh and when placed in water has a tendency to "ball up" and not disperse and produces dust when handled in the large quantities needed on a plant scale. The results of these tests indicate no difference in BOD reduction between KWK bentonite and 200 mesh bentonite. The results are shown in Table 7.

Tests were also run to determine if bentonite prepared in a more concentrated suspension as necessary on a plant-scale woud change its effectiveness. Laboratory scale tests had been run using a .3% suspension. This was increased to 6.0% This increase in concentration of the feed solution did greatly reduce its efficiency as indicated in Table 8.

Table 5

Polyelectrolytes Given More Extensive Lab Testing
(Average Of 8 To 10 Trials)
Polyelectrolyte Dosage - 0.5 mg/l

Sample	BOD mg/l	Percent Reduction From Untreated	Inc. Treatment Percentage Points Above Control
Control #1	940	34.6	--
Blaisdell & Klaas #1	682	52.7	18.1
*Rohm & Haas A-10	728	49.4	14.8
*Nalco 675	735	49.0	14.4
*Goodyear's 708	705	51.0	16.4
Control #2	967	38.5	--
Blaisdell & Klaas #2	712	54.8	16.3
*A-1004 National Starch 3286	721	54.2	15.7
Control #3	1079	30.9	--
Blaisdell & Klaas #3	809	48.3	--
*General Mills 263	772	50.6	19.7
*General Mills 162	758	51.6	20.7
*Nalco's D-2073	787	49.7	18.8
*Garratt-Callahan #78	768	50.9	20.0
Control #4	1286	33.0	--
Blaisdell & Klaas #4	962	50.0	17.0
*Hercules 220	913	52.5	19.5

Table 5 (Continued)

Sample	BOD mg/l	Percent Reduction From Untreated	Inc. Treatment Percentage Points Above Control
Control #5	935	42.6	--
Blaisdell & Klaas #5	675	58.6	16.0
Nalco's 607	693	57.5	14.9
Nalco's 610	680	58.2	15.6
Control #6	927	41.2	--
Blaisdell & Klaas #6	670	57.5	16.3
*Tylite #9	662	58.0	16.8
Control Average	979	36.8	--
Blaisdell & Klaas Ave.	751	53.6	16.8

*Potential samples for plant scale test

POLYELECTROLYTE SCREENING
INCREASED TREATMENT
PERCENTAGE POINTS ABOVE CONTROL

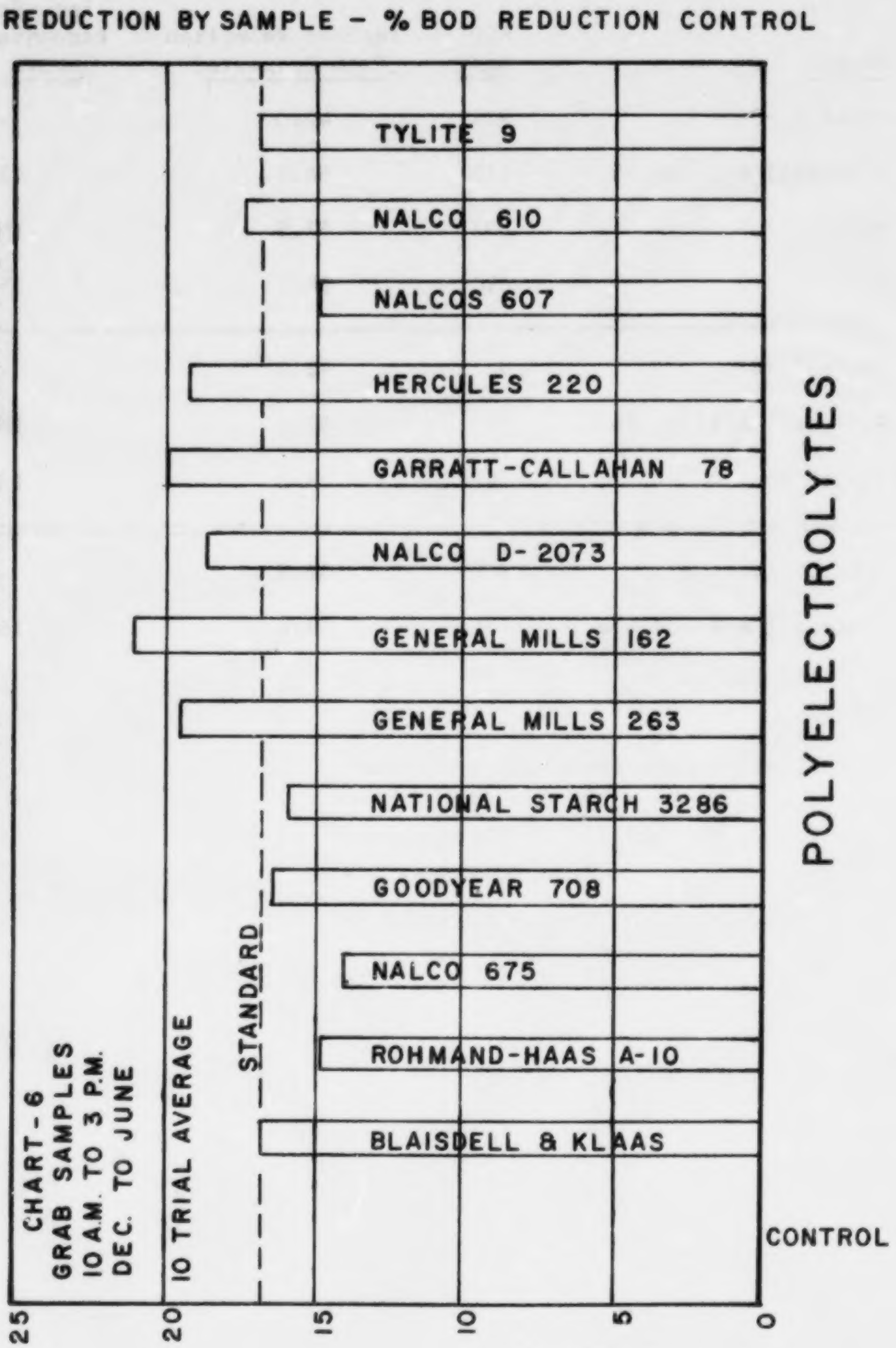


FIGURE-6

Table 6

Effectiveness Of Sodium & Calcium Bentonite In BOD Removal

Trial	Untreated BOD mg/l	Blank* BOD mg/l	Sodium Bentonite 60 mg/l BOD mg/l	Sodium Bentonite 120 mg/l BOD mg/l	Calcium Bentonite 60 mg/l BOD mg/l	Calcium Bentonite 120 mg/l BOD mg/l
1	--	1015	870	790	900	920
2	1475	960	935	760	990	985
3	1609	1275	1070	960	1260	1095
4	1540	1095	1095	845	1045	1075
Average	1541	1086	992	839	1049	1019
Reduction	--	29.4%	35.7%	46.6%	31.9%	33.9%

Sodium Bentonite vs. Calcium Bentonite at 120 mg/l $t= 8.78$ $p < .01$

* Stirred and settled, no chemicals added

Table 7

Effectiveness Of Different Forms Of Sodium Bentonite In Lab Tests

Sample	BOD mg/l	% Reduction
Untreated	2002	--
Bentonite 200 In Water	843	57.9
Bentonite KWK In Water	896	55.5
Bentonite KWK Added Dry	1062	46.8

Table 8

Effect Of Concentration Of Bentonite Suspension

Sample	BOD mg/l	% Reduction
Untreated	1867	--
0.3% Bentonite Distilled Water	931	49.9
0.3% Bentonite City Water	945	49.4
6.0% Bentonite City Water	1116	40.1

A series of laboratory tests were run on several samples of iron ore to determine what effect the weighting agent would have and which type of iron ore would be most effective. When only 1 mg/l of iron ore was added to 1 liter of tap water, no perceptable amount could be seen. It was necessary to increase the dosage to above 10 mg/l before the ore was observable.

Tests were run on two grades of hematite (non-magnetic) and two grades of magnetite. The magnetite was of a fine mesh resulting from the taconite process of refining iron ore. Both magnetite samples were run in magnetized form and demagnetized form.

Samples were run using the chemical dosages (see page20) used to screen polyelectrolytes with the only variable being the iron ore. The dynamic settling technique was used. Samples were drawn off the surface of the one liter beaker while it was being stirred at a low rpm in the jar test equipment. Thirty mg/l of iron ore were added to give a more pronounced effect.

Results of the test are shown in Table 9. Hematite No. 1 was slightly coarser and of more uniform size than hematite No. 2. In both, 80% would be retained by a 150 mesh screen. Both samples of magnetite were more finely divided than the hematite. Magnetite No. 1 44% would pass a 325 mesh screen and Magnetite No. 2 90% would pass a 325 mesh screen.

Results of this single run were somewhat inconclusive. The difference in percent reduction observed was not large enough to be considered meaningful.

Table 9

Weighting Agent Laboratory Tests

Sample	Suspended Solids mg/l	% Reduction
Raw sewage used for testing purposes	750	--
Control - treated with flocculant but no iron ore	306	59.1
All samples treated with flocculant plus iron ore	262	65.1
Hematite		
No. 1 only	275	63.3
No. 2 only	215	71.3
Average of No.'s 1 and 2	245	67.3
Magnetite		
No. 1, magnetized and demagnetized	255	66.0
No. 2, magnetized and demagnetized	296	60.5
Samples 1 and 2, magnetized only	267	64.4
Samples 1 and 2, demagnetized only	271	63.9
All magnetized samples	270	64.0

SECTION VI

PLANT-SCALE EVALUATION OF PATENTED PROCESS

In October of 1968, pilot plant scale tests were started on the Blaisdell and Klass process, but operating difficulties resulting from the corrosiveness of the ferric chloride solution delayed the actual testing until November 1968.

These tests were run using concentrations of chemicals proven successful in laboratory tests. The polyelectrolytes used were National Starch Floc Aid 1038 on the cationic side and Monsanto's Stymer-S on the anionic side. Testing was run on two shifts starting at 8:00 a.m. in the morning and ending at midnight. These tests were run for a two week period during which seven days of data were collected. The chemical dosages used were 120 mg/l of bentonite and 0.06 mg/l of Stymer-S on the anionic side. The chemical dosage of the cationic side was 0.5 mg/l of 1038 starch, 1.0 mg/l of iron ore and 1.5 mg/l of ferric chloride. This was the 1:2:3 ratio of chemicals recommended by the patent holders. The bentonite suspension was prepared at 8% solids. The starch 1038 was mixed first in hot water in small drums and then mixed with ferric chloride and iron ore in the 500 gallon container. The concentration of the resulting mixture of cationic chemicals was 2%. The cationic chemicals and anionic chemicals were added separately to two parallel streams of wastewater in the two small flash mixing chambers and these were then combined in the large flash mixing chamber.

Samples were taken at the influent to the mixing chambers before any chemicals were added and at the effluent to the test and control tank. These samples were taken hourly and an 18 hour composite was made on the basis of flow. Hourly settleable solids were run on grab samples but all other tests were run on the composite sample. The primary parameter being tested was BOD. Suspended solids analysis was also run on the composite sample. The results of the BOD and suspended solids test are given in Table 10. Results of a "Student" t-test on the data indicates significant reduction was not accomplished in either BOD or suspended solids during the seven days of testing.

Since previous laboratory tests had indicated the effectiveness of bentonite was dependent on a dilute concentration of the material being added, lower concentrations of bentonite were tried for several days. The screen testing period was limited to two days adding bentonite at a concentration of 2.7%. The results of these screen tests are shown in Table 11. Even at this reduced concentration of the bentonite no meaningful reduction in BOD was observed by the addition of chemicals. This method was successful in the laboratory, but it had no effect when used in a plant scale process.

ADDITIONAL PATENTED MODIFICATION EVALUATIONS

After this process failed, one of the patent holders suggested a number of variations in the patented process to effect a BOD reduction in the wastewater by means of chemical additions. Over a six-month period, from December 1968 to June 1969, 23 variations were tried.

No. 1

Starting the end of December 1968, and going into January 1969 a five-day series of tests were run increasing the dosage of cationic chemicals and decreasing the dosage of anionic chemicals. The cationic and anionic chemicals were both added at 50 mg/l of the total mixture on

Table 10

Plant Scale Tests
Chemical Dosage Anionic 120 mg/l Cationic 3 mg/l
Bentonite Prepared At 8%

Reduction Of BOD mg/l

Date	Influent	Effluent Test Tank	Percent Reduction	Effluent Control Tank	Percent Reduction
Nov., 1968					
4	1050	930	11.3	935	10.9
5	1230	800	35.0	800	35.0
6	1620	1005	38.0	1070	33.9
8	1015	820	19.2	800	21.2
12	1425	865	39.3	870	38.9
13	1450	930	35.9	970	33.1
14	1485	920	38.0	940	36.7
Average	1325	896	32.4	912	31.2

t= 1.55 p= .17

Reduction Of Suspended Solids mg/l

Date	Influent	Effluent Test Tank	Percent Reduction	Effluent Control Tank	Percent Reduction
Nov., 1968					
4	450	340	--	290	--
5	900	370	--	290	--
6	930	400	--	150	--
12	610	220	--	290	--
13	570	270	--	150	--
14	810	210	--	160	--
Average	711	301	57.7	221	69.0

t= 1.87 p= .12

Table 11

Plant Scale Tests
Chemical Dosage Anionic 120 mg/1, Cationic 3 mg/1

Bentonite Prepared at 4% Solids
Reduction of BOD mg/1

Date Nov. 1968	Influent	Effluent Test Tank	% Reduction	Effluent Control Tank	% Reduction
25	1100	815	--	800	--
26	1500	950	--	915	--
AVERAGE	1300	880	32.3	855	34.2

Bentonite Prepared at 2.7% Solids
Reduction of BOD mg/1

Date Nov. 1968	Influent	Effluent Test Tank	% Reduction	Effluent Control Tank	% Reduction
28	1780	1020	--	1085	--
29	1445	885	--	910	--
AVERAGE	1610	950	41.0	1000	38.0

each side. Bentonite (KWK) was added at 50 mg/l with Stymer-S added at .025 mg/l. Starch was added at 8.3 mg/l, iron ore at 16.7 mg/l, and ferric chloride at 25 mg/l. The starch used in this and subsequent tests was National Starch Floc Aid 1063. This starch did not require as high a temperature in its preparation as the Floc Aid 1038. The ferric chloride and iron ore were mixed in one tank and the starch in the second cationic tank. Separate pumps were obtained to pump the chemicals from the tanks. To avoid possible degradation of the starch by the acidic ferric chloride solution. The ferric chloride tank was refilled while chemicals were being fed and the starch pump was shut down daily for 20 minutes to allow refilling. The results are shown in Table 12. Significant effects could not be observed by the addition of chemicals.

No. 2

A four-day test was run with chemical dosage at 30 mg/l each for cationic and anionic chemicals. The specific dosages were: 30 mg/l bentonite (KWK), .015 mg/l Stymer-S, 5 mg/l Floc Aid 1063, 10 mg/l iron ore, and 15 mg/l ferric chloride. The results are shown in Table 13. Again, floc was not visible nor was any significant reduction in BOD and suspended solids achieved.

No. 3

Two days of testing were conducted adding 15 mg/l each of cationic and anionic chemicals. The specific dosages of chemicals were in the same ratio as in the previous three tests. Again, no meaningful reduction was achieved. The results are given in Table 14.

Table 12

Plant Scale Tests
No. 1

Chemical Dosage 50 mg/l Cationic 50 mg/l Anionic
Reduction of BOD mg/l

Date	Influent	Test Tank Eff.	% Reduction	Control Tank Eff.	% Reduction
Dec. 27, 1968	1440	1250	13.1	1240	13.8
Jan. 2, 1969	1360	1020	25.0	990	27.0
Jan. 3, 1969	1595	1090	31.6	1310	17.9
Jan. 7, 1969	1710	1143	32.9	1398	18.3
*Jan. 15, 1969	1950	1470	24.5	1120	42.2
Average	1611	1195	25.7	1212	24.7

t= .153 p= .88

Chemical Dosage 50 mg/l Cationic 50 mg/l Anionic
Reduction of Suspended Solids mg/l

Date	Influent	Test Tank Eff.	% Reduction	Control Tank Eff.	% Reduction
Dec. 27, 1968	740	590	20.1	510	31.0
Jan. 2, 1969	670	300	55.2	240	64.1
Jan. 3, 1969	650	290	55.4	390	40.0
Jan. 7, 1969	1010	460	54.5	610	39.6
*Jan. 15, 1969	1040	500	48.1	210	79.8
Average	822	428	47.8	392	52.3

t= .466 p= .77

* A new ferric chloride pump was installed.

Table 13

Plant Scale Tests No. 2
Chemical Dosage 30 mg/l Cationic 30 mg/l Anionic

Reduction of BOD mg/l

Date	Influent	Test Tank Eff.	% Reduction	Control Tank Eff.	% Reduction
Jan. 16, 1969	1330	930	30.0	970	27.1
Jan. 17, 1969	1345	925	31.4	1015	24.5
Jan. 21, 1969	--	--	--	--	--
Jan. 22, 1969	1265	855	32.5	880	30.5
Average	1313	903	31.3	955	27.1

$t = 2.65$ $p = .13$

Reduction of Suspended Solids mg/l

Date	Influent	Test Tank Eff.	% Reduction	Control Tank Eff.	% Reduction
Jan. 16, 1969	740	470	36.5	390	47.4
Jan. 17, 1969	630	400	36.5	450	28.5
Jan. 21, 1969	570	180	68.5	200	64.9
Jan. 22, 1969	470	160	66.0	210	55.3
Average	602	302	49.8	312	48.1

$t = .324$ $p = .77$

Table 14

Plant Scale Tests No. 3
Chemical Dosage 15 mg/l Cationic 15 mg/l Anionic

Reduction of BOD mg/l

Date	Influent	Test Tank Eff.	% Reduction	Control Tank Eff.	% Reduction
Jan. 23, 1969	1545	1135	26.5	1005	35.0
Jan. 24, 1969	1255	930	26.0	905	27.9
Average	1410	1032	26.6	955	32.3

Reduction of Suspended Solids mg/l

Date	Influent	Test Tank Eff.	% Reduction	Control Tank Eff.	% Reduction
Jan. 23, 1969	760	400	47.4	380	50.0
Jan. 24, 1969	560	140	75.0	170	69.6
Average	660	270	59.1	275	58.3

No. 4

Two days of tests were run adding concentrations of 15 mg/l cationic chemicals and 45 mg/l of anionic chemicals. The specific doses were: 45 mg/l bentonite (KWK), .022 mg/l Stymer-S, 2.5 mg/l Floc Aid 1063; 5.0 mg/l iron ore; and 7.5 mg/l ferric chloride. The results of this trial are shown in Table 15.

A substantial reduction was made in suspended solids on the first day, but not on the second. A dense floc was not produced and the BOD reduction was slight. Further tests at this concentration were not made.

No. 5

In February 1969, a different grade of bentonite was tried. A 200 mesh bentonite was used instead of KWK 40 mesh bentonite. The doses were: 20 mg/l bentonite, .015 mg/l Stymer-S, 5 mg/l Floc Aid 1063 and 15 mg/l ferric chloride. BOD reduction was not obtained. The results are given in Table 16.

No. 6

Some short tests adding high dosages of chemicals to the wastewater indicated a fine floc could be formed at dosages of 50 to 100 mg/l of ferric chloride. Four days of testing were done with the dosage of 50 mg/l ferric chloride. The dosages of the other chemicals added were: 30 mg/l, Bentonite (KWK); .015 mg/l, Stymer-S; 5 mg/l, Floc Aid 1063, and 10 mg/l iron ore. The results are shown in Table 17. Again, significant BOD reduction was not achieved.

Table 15

Plant Scale Tests No. 4
Chemical Dosage 15 mg/l Cationic 45 mg/l Anionic

Reduction of BOD mg/l

Date	Influent	Test Tank Eff.	% Reduction	Control Tank Eff.	% Reduction
Jan. 27, 1969	1260	885	29.8	890	29.5
Jan. 31, 1969	995	800	19.5	835	16.0
Average	1128	842	24.6	862	23.4

Reduction of Suspended Solids mg/l

Date	Influent	Test Tank Eff.	% Reduction	Control Tank Eff.	% Reduction
Jan. 27, 1969	450	170	62.2	380	16.5
Jan. 31, 1969	420	210	50.0	230	45.3
Average	435	180	58.5	305	29.8

Table 16

Plant Scale Tests
No. 5

200 mesh bentonite
Starch and ferric chloride in separate tanks

Chemical Dosage 30 mg/l Cationic 30 mg/l Anionic

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
Feb. 5, 1969	1090	865	900
Feb. 6, 1969	1370	920	895
Average	1230	892	898
Percent Reduction	--	27.5	27.0

Table 17

Plant Scale Tests
No. 6

Starch separate from ferric chloride and iron ore
Chemical Dosage: Bentonite at 30 mg/l, Ferric Chloride at 50 mg/l, Iron ore at 10 mg/l, Starch at 5 mg/l, Stymer-S at .015 mg/l

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
Feb. 4, 1969	1155	915	930
Feb. 7, 1969	1435	1035	1010
Feb. 12, 1969	1325	1123	1042
Feb. 13, 1969	1470	895	900
Average	1346	992	970
Percent Reduction	--	26.4	27.9

t= .972 p= .40

No. 7

Two days of testing were run with the dosages of chemicals used in test No. 6, but with the flash mixers shut off. It was thought the flash mixers might be shearing the floc and it was not reforming. The results are shown in Table 18. Slightly greater BOD reduction was achieved in the test tank as compared to the control tank, but the difference was not great enough to justify the use of chemicals.

No. 8

A series of six days of testing were run with the flow of wastewater reduced to give 1 1/2 hour detention in the primary sedimentation tank. The chemical dosages were the same as in tests No. 6 and No. 7. The results are shown in Table 19. A significantly greater BOD reduction was achieved in the test tank than in the control tank. This could be experienced since this high dosage of ferric chloride formed a fine floc which would settle out given a long detention time but would not settle out at the normal rate of flow through the tank. Since the object was to form a heavy floc which would incorporate the weighting agent and then settle out in a short detention time, further variations in the patented process were continued.

The patent holders recommended a change in the cationic polyelectrolyte to achieve a heavy floc. Polyethylene imine (PEI) was used instead of the modified starch which had been used. It was the opinion of the patent holders that the PEI while considerably more expensive was much more effective in the formation of a floc.

No. 9

Two days of tests were run using the same dosages of chemicals used in tests No. 6, 7, and 8, but substituting the PEI for Floc Aid 1063. No substanial floc formation was observed other than that formed by the

Table 18

Plant Scale Tests
No. 7

Flash mixers off, starch separate from ore and ferric chloride

Chemical Dosage same as Table 17

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
Feb. 14, 1969	1585	1000	1050
Feb. 17, 1969	1540	800	850
Average	1562	900	1000
Percent Reduction	--	42.5	36.0

Table 19

Plant Scale Tests
No. 8

Detention time 1½ hours, starch separated from ferric chloride and iron ore.

Chemical Dosage: Iron ore at 10 mg/l, Bentonite at 30 mg/l, Ferric Chloride at 50 mg/l, Starch at 5 mg/l, Stymer-S at .015 mg/l

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
Feb. 18, 1969	1125	595	712
Feb. 19, 1969	1255	635	755
Feb. 21, 1969	1690	675	810
Feb. 24, 1969	1020	688	726
Feb. 25, 1969	1235	655	830
Feb. 26, 1969	1140	633	700
Average	1244	647	755

$t = 5.425$ $p < .01$

50 mg/l of ferric chloride. On the first day the detention period in the test and control settling tanks was increased to 1 1/2 hours. A BOD reduction due to chemicals was observed which was about the same as that observed when 50 mg/l of ferric chloride had been added in combination with the Floc Aid 1063 and other chemicals being used. The results are shown in Table 20.

No. 10

The patent holders suggested a more effective means of incorporating the iron ore into the floc would be to mix it with the polyelectrolyte rather than with the ferric chloride as had been done in previous tests. A four day test was run mixing the ferric chloride in one tank and the Floc Aid 1063 in the other tank. The dosage of chemicals were: 30 mg/l Bentonite,0.015 mg/l Stymer-S,5 mg/l Floc Aid 1063, 10 mg/l iron ore, and 50 mg/l ferric chloride. The results of these tests did not indicate any significant BOD removed by the chemicals nor was any heavy floc formed. Only the fine floc, resulting from the 50 mg/l of ferric chloride was produced. The results are indicated in Table 21.

No. 11

Two days of testing were done following the same procedure, but using PEI instead of Floc Aid 1063. The iron ore was mixed in with the PEI and the ferric chloride was mixed separately. The same concentration of chemicals was used. Again, no appreciable floc was formed and no substantial reduction in BOD or suspended solids was obtained. The data is presented in Table 22.

Table 20

Plant Scale Tests
No. 9

Polyethylene imine mixed separately from the ferric chloride and iron ore.
Chemical Dosage: Bentonite at 30 mg/l, Iron ore at 10 mg/l, Ferric Chloride at 50 mg/l, Polyethylene imine at 5 mg/l, Stymer-S at .015 mg/l

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
Normal Flow			
Feb. 20, 1969	1120	770	840
Percent Reduction	--	31.4	25.0
Reduced Flow			
February 27, 1969	1270	710	825
Percent Reduction	--	44.2	35.1

Table 21

Plant Scale Tests
No. 10

Iron ore mixed with starch; ferric chloride mixed separately
Chemical Dosage: Bentonite at 30 mg/l, Iron ore at 10 mg/l, Ferric Chloride at 50 mg/l, Starch at 5 mg/l, Stymer-S at .015 mg/l

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
March 3, 1969	1260	830	790
March 4, 1969	1540	910	920
March 5, 1969	1830	845	920
March 6, 1969	1450	1010	955
Average	1520	899	896
Percent Reduction	--	40.9	41.0

$t = .085$ $p > .90$

Table 22

Plant Scale Tests
No. 11

P.E.I. and iron ore mixed, Ferric chloride mixed separately, mechanical flocculators on

Chemical Dosage: Bentonite at 30 mg/l, Iron ore at 10 mg/l, Ferric Chloride at 50 mg/l, P.E.I. at 5 mg/l, Stymer-S at 0.015 mg/l

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
March 17, 1969	1370	685	845
March 19, 1969	1950	1170	1210
Average	1660	927	1027
Percent Reduction	--	44.2	38.1

Reduction Of Suspended Solids mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
March 17, 1969	530	140	150
March 19, 1969	850	320	290
Average	690	230	220
Percent Reduction	--	65.7	68.1

No. 12

It was suggested by the patent holders that perhaps packinghouse grease was being emulsified in the flash mixers, thereby creating a large surface upon which the chemicals were absorbed, reducing their effectiveness. To test the idea, a single day's run was made with the flash mixers and mechanical flocculators shut off. The iron ore was mixed with the starch and the ferric chloride was mixed separately. The dosages were the same as had been used in previous tests. The results are given in Table 23. For this one day's run, there appeared to be some reduction in BOD and suspended solids.

No. 13

The mechanical flocculators were possibly shearing the floc and reducing its size. Five days of tests were conducted with the mechanical flocculators shut off, but with the flash mixers on. The specific dosage of chemicals used were the same as had been used in previous tests: 30 mg/l, bentonite; 0.015 mg/l, Stymer-S; 5 mg/l Floc Aid 1063; 10 mg/l iron ore and 50 mg/l ferric chloride. The iron ore was again mixed with the starch and the ferric chloride mixed separately. The mechanical flocculators were not operated. The results are given in Table 24. Again, some reduction appeared in BOD and suspended solids, however substantial floc formation was not visible. The t-test for significance of difference betwen two means was run on data of both the suspended solids and BOD tests. The results indicated no significant difference in suspended solids between the test and control tank. The BOD did show a difference between the test and control tank which was significant. However, the efficiency of the BOD reduction in this test was not as great as was hoped for.

Table 23

Plant Scale Tests
No. 12

Flash mixers and flocculators off.

Chemical Dosage: Bentonite at 30 mg/l, Iron ore at 10 mg/l, Ferric Chloride at 50 mg/l, Starch at 5 mg/l, Stymer-S at 0.015 mg/l

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
March 21, 1969	1272	675	830
Percent Reduction	--	47.0	34.9

Reduction Of Suspended Solids mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
March 21, 1969	820	90	150
Percent Reduction	--	89.0	81.7

Table 24

Plant Scale Tests
No. 13

Mechanical flocculators off.

Chemical Dosage: Bentonite at 30 mg/l, Iron ore at 10 mg/l, Ferric Chloride at 50 mg/l, Starch at 5 mg/l, Stymer-S at 0.015 mg/l

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
March 24, 1969	1040	650	735
March 25, 1969	1350	810	1005
March 26, 1969	1243	698	1022
March 27, 1969	1577	857	1262
March 28, 1969	1235	762	907
Average	1289	755	986
Percent Reduction	--	41.4	23.2

t= 3.93 p= .03

Reduction Of Suspended Solids mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
March 24, 1969	730	260	210
March 25, 1969	570	150	200
March 26, 1969	710	110	720*
March 27, 1969	380	130	220
March 28, 1969	500	170	280
Average	578	164	227
Percent Reduction	--	71.6	60.7

*Excluded from average t= 1.47 p= .24

No. 14

Several days of tests were conducted at a reduced dosage of 30 mg/l ferric chloride. All other chemical dosages and procedures were kept the same. The mechanical flocculators were left off. The results of these tests are shown in Table 25. Again, large floc was not obtained and the BOD reduction obtained by use of chemicals was not significant as indicated by the results of the "Student" t-test run on data in Table 25.

No. 15

A one day test was run without any anionic chemicals and adding the cationic chemicals in the following dosages: 5 mg/l, Floc Aid 1063, 10 mg/l, iron ore, and 15 mg/l ferric chloride. The mechanical flocculators were left off. Large floc was not formed. BOD reduction was achieved as indicated in Table 26, but not enough to consider the systems effective.

No. 16

A Five-day test was run using the same cationic dosages but adding 8 mg/l of bentonite along with it. Large floc was not formed and the results did not indicate a significant reduction in BOD. The results are shown in Table 27.

No. 17

The chemical feed was further reduced. The dosages added were: 4 mg/l, Bentonite, .002 mg/l, Stymer-S, 3 mg/l, Floc Aid 1063, 6 mg/l iron ore, and 9 mg/l ferric chlorde. The mechanical flocculators were left off. Again, floc was not formed. A slight increase in BOD reduction

Table 25

Plant Scale Tests
No. 14

Mechanical flocculators off

Chemical Dosage: Bentonite at 30 mg/l, Iron ore at 10 mg/l, Ferric Chloride at 30 mg/l, Starch at 5 mg/l, Stymer-S at 0.015 mg/l

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
March 31, 1969	1247	682	845
April 1, 1969	1260	993	945
April 2, 1969	1562	760	845
Average	1356	812	878
Percent Reduction	--	39.3	35.2

t= 1.087 p= .40

Reduction Of Suspended Solids mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
March 31, 1969	550	80	380
April 1, 1969	550	150	260
April 2, 1969	940	240	300
Average	680	157	313
Percent Reduction	--	76.9	54.0

t= 2.148 p= .17

Table 26

Plant Scale Tests
No. 15

Flocculators off
Chemical Dosage: Ferric chloride at 15 mg/l, Starch at 5 mg/l, Iron ore at 10 mg/l, Bentonite - none, Stymer-S - none

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
April 3, 1969	1080	610	807
Percent Reduction	--	43.5	25.3

Reduction Of Suspended Solids mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
April 3, 1969	510	180	270

Table 27

Plant Scale Tests
No. 16

Chemical Dosage: Ferric chloride at 15 mg/l, Iron ore at 10 mg/l Starch at 5 mg/l, Bentonite at 8 mg/l, Stymer-S at 8/2000 mg/l

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
April 4, 1969*	748	446	521
April 7, 1969	1155	780	975
April 8, 1969	1275	717	704
April 9, 1969	1375	717	745
April 10, 1969	1060	765	803
April 11, 1969	940	607	702
Average	1157	717	786
Percent Reduction	--	37.9	32.0

t= 1.906 p= 0.14

*Good Friday - low flow, excluded from average was achieved as indicated in Table 28. A statistical t-test did not indicate this difference to be significant at the 0.05 level. The actual improvement was 110 mg/l.

It appeared that slight BOD reduction was being achieved, but was not considered enough to justify the use of chemicals. The fact that some BOD reduction was now being achieved while none had been achieved in earlier tests was attributed to mechanical flocculators, which were not now being operated, shearing the floc.

No. 18

A three day series of tests were run with the flash mixers and the mechanical flocculators shut off. The chemical dosages were: 8 mg/l, bentonite, 5 mg/l, Floc Aid 1063, 10 mg/l, iron ore, and 15 mg/l ferric chloride. Again floc was not formed. The results indicated no difference in BOD or suspended solids reduction (Table 29).

No. 19

Anionic and cationic chemical addition was changed from parallel to series. A concentration of 37.5 mg/l ferric chloride was added to the variable speed flash mixer along with .022 mg/l Stymer-S. National Starch Floc Aid 1063 was added at a point just beyond the large flash mixer. (Figure 2). Turbulence in the flume leading to the settling tank plus the mechanical flocculators was sufficient to provide mixing of the starch with the wastewater. The results are shown in Table 30. Reduction of BOD and suspended solids were obtained, but not enough to justify continuing the test. A large or dense floc was not formed.

Table 28

Plant Scale Tests
No. 17

Flocculators off

Chemical Dosage: Ferric chloride at 9 mg/l, Iron ore at 6 mg/l, Starch at 3 mg/l, Bentonite at 4 mg/l, Stymer-S at 4/2000 mg/l

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
April 28, 1969	1240	735	1130
April 29, 1969	1805	800	940
April 30, 1969	1315	922	998
May 1, 1969	1447	770	960
May 2, 1969	1215	802	750
Average	1404	845	955
Percent Reduction	--	39.9	32.1

t= 1.921 p= .14

Table 29

Plant Scale Tests
No. 18

Flash mixers off, flocculators off

Chemical Dosage: Ferric chloride at 15 mg/l, Iron ore at 10 mg/l, Starch at 5 mg/l, Bentonite at 8 mg/l, Stymer-S at 8/2000 mg/l*

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
May 5, 1969	1250	775	890
May 6, 1969	1305	950	830
May 7, 1969	767	457	478
Average	1107	727	733
Percent Reduction	--	34.3	33.7

t= .218 p= .85

Reduction Of Suspended Solids mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
May 5, 1969	700	240	270
May 6, 1969	670	230	180
May 7, 1969	470	90	100
Average	613	187	187
Percent Reduction	--	69.5	69.5

t= .138 p=>.90

* 8 parts of Stymer-S mixed with 2000 parts of Bentonite

Table 30

Plant Scale Tests
No. 19

Starch into parshall flume following parallel addition of bentonite and ferric chloride

Chemical Dosage: Ferric chloride at 37.5 mg/l, Iron ore - none, Starch at 3 mg/l, Bentonite at 4 mg/l, Stymer-S at 4/2000 mg/l

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
May 13, 1969	1430	580	820 (1 grab sample)
May 14, 1969	1040	917	982 (3 samples comp)
Average	1223	748	901
Percent Reduction	--	39.0	26.4

Reduction Of Suspended Solids mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
May 13, 1969	900	160	300
May 14, 1969	260*	300	310
Average	580	230	305
Percent Reduction	--	60.2	47.4

* Probably atypical results

No. 20

Two days of tests were run using the same procedure but at reduced rate of chemicals. The dosages were: 9mg/l, ferric chloride, no iron ore, 3 mg/l starch, 4 mg/l bentonite and .002 mg/l Stymer-S

No. 21

Two days were run adding iron ore mixed with 6 mg/l ferric chloride, but with no bentonite and Stymer-S.

No. 22

A final two days of tests were run with all the chemicals added. The results are shown in Tables 31-33. No effective floc formation was achieved and the BOD reduction was very small.

No. 23

The patent holder suggested the order of addition of chemicals be changed. Bentonite and .002 mg/l Stymer-S were added to both small flash mixers in a split stream. Ferric chloride and iron ore mixed together were added to the large flash mixer and Floc Aid 1063 was added to the flume just beyond the large flash mixer. These tests were run for four days. The results are indicated in Table 34. Floc production was not effective and significant reduction of suspended solids or BOD was not achieved. Very little success was obtained from any of the variations tried. At no time was a dense floc formed during any of these tests.

By June 1969 six months of testing of the Blaisdell and Klaas patented procedure for wastewater flocculations and sedimentation had been run without success. Of all procedures tried at the South St. Paul treatment plant none achieved a sufficient reduction in BOD and suspended solids.

Table 31

Plant Scale Tests
No. 20

Starch into parshall flume following parallel addition of bentonite and ferric chloride

Chemical Dosage: Ferric chloride at 9 mg/l, Iron ore - none, Starch at 3 mg/l, Bentonite at 4 mg/l, Stymer-S at 4/2000 mg/l

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
May 15, 1969	835	650	712
May 13, 1969	1345	535	585
Average	1090	592	648
Percent Reduction	--	45.8	40.6

Reduction Of Suspended Solids mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
May 15, 1969	430	110	250
May 16, 1969	730	150	180
Average	580	130	215
Percent Reduction	--	77.6	62.9

Table 32

Plant Scale Tests
No. 21

$FeCl_3$ and iron ore mixed; starch into the parshall flume following parallel addition of bentonite and ferric chloride

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
May 19, 1969	930	625	650
May 20, 1969	1115	640	798
Average	1022	632	724
Percent Reduction	--	38.2	29.2

Reduction Of Suspended Solids mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
May 19, 1969	500	210	200
May 20, 1969	570	430	280
Average	535	320	240
Percent Reduction	--	40.2	45.2

Table 33

Plant Scale Tests
No. 22

Iron ore and ferric chloride mixed together. Starch added to the parshall flume following parallel addition of bentonite and ferric chloride

Chemical Dosage: Ferric chloride at 9 mg/l, Iron ore at 6 mg/l, Starch at 3 mg/l, Bentonite at 4 mg/l, Stymer-S at 4/2000 mg/l

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
May 21, 1969	1010	685	610
May 22, 1969	1050	680	760
Average	1030	682	685
Percent Reduction	--	33.8	33.5

Reduction Of Suspended Solids mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
May 21, 1969	430	140	190
May 22, 1969	550	190	220
Average	490	165	205
Percent Reduction	--	66.3	58.2

Table 34

Plant Scale Tests
No. 23

Bentonite added to the two small flash mixers. Ferric chloride and iron ore premixed and added to the large flash mixer. Starch added to the parshall flume.

Chemical Dosage: Ferric chloride at 9 mg/l, Iron ore at 6 mg/l, Starch at 3 mg/l, Bentonite at 4 mg/l, Stymer-S 4/2000 mg/l

Reduction Of BOD mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
May 26, 1969	1322	915	922
May 27, 1969	1517	872	867
May 28, 1969	1040	689	700
May 29, 1969	1045	805	785
Average	1181	820	818
Percent Reduction	--	30.7	30.6

t= .250 p= .85

Reduction Of Suspended Solids mg/l

Date	Influent	Test Tank Effluent	Control Tank Effluent
May 26, 1969	690	160	220
May 27, 1969	570	280	280
May 28, 1969	570	230	260
May 29, 1969	490	180	170
Average	580	212	232
Percent Reduction	--	63.5	60.0

t= 1.27 p= .39

There was no success in producing a floc beyond what could be expected from the higher doses of ferric chloride added during some of the tests. During this six month period one of the patent holders, a practicing engineer, had acted as a consultant and visited the plant on an average of once a week. In addition, field representatives from the companies whose products were being used in the tests had visited the plant providing advice on methods they had found successful at plants treating wastewater other than packinghouse wastes. Success was not had in flocculating the combined mixture of domestic, stockyards, and packing house wastes.

A total of 11 of the 23 tests were run for a long enough time to provide sufficient data for statistical analysis of difference in the means of the test and control effluents by the "Student" t-test. The other 12 tests were terminated with three or less days run because a dense floc was not being formed or because the reduction of BOD and suspended solids was not considered enough to justify the use of chemical treatment.

Only 2 of the 11 showed a significant difference in BOD reduction between the test and control tanks. These were tests No. 8 and No. 13. The results of test No. 8 were obtained by increasing the dosage of ferric chloride to produce a fine floc and increasing the detention time in the test and control tank to 1 1/2 hours. At the normal wastewater flow through the three primary tanks of 1 1/2 hours detention time could not be achieved and the BOD reduction was not obtained without it as indicated in test No. 6. Analysis for suspended solids was not run on test No. 8.

The second test in which a significant BOD reduction was obtained was test No. 13. The reduction obtained in suspended solids data was not significant. This test was run with the mechanical flocculators shut off. The chemical dosage was the same as had been used in test No. 8. The cost of chemicals was $11.69 per million liter ($44.20 per million gallons). If costs for labor, utilities, capital construction and maintenance were included, the total cost of chemical treatment would be about $15.00 per million liter ($58.00 per million gallons). This cost was too high to be practical considering the amount of BOD reduction obtained. A number of additional tests were made with the mechanical flocculators off and reduced chemical dosage, but a significant difference in BOD and suspended solids was not obtained.

SECTION VII

LABORATORY EVALUATION OF NON-PATENTED SYSTEMS

Advice was sought of experienced persons in the use of organic and inorganic flocculating agents in wastewater, and who did not have a proprietary interest in the success of the patented process being treated or in any chemical flocculating agent or combination thereof.

Personnel from EPA laboratories were asked to provide assistance in an effort to determine if successful treatment could be achieved by the use of chemical additions. EPA personnel came to the South St. Paul plant site to review previous grant reports, make on-site inspection of plant facilities, and considerable laboratory work was performed in screening of polyelectrolytes or systems of polyelectrolytes to determine what would be effective in flocculation of the combined South St. Paul wastewater. In reviewing the results of over 20 different test conditions of the patented process which had been tested at the plant, no large difference was found between test conditons and control results for most tests. The differences shown were in the same range as the differences between the test and control tank without chemical additives.

A malfunction of the flow meter in the test channel was discovered and corrected.

Several variations of the patented process were tested and found to be inactive with the combined wastewater at the plant. As a result of this, it was recommended that evaluation of the patented chemical process be discontinued until the patent holders had found and demonstrated active mixtures in the laboratory.

A number of single and dual systems of chemical flocculating agents were tested. In addition, lab tests were run for flocculation consistency for those chemical systems which produced a satisfactory floc.

A single system is the most practical from the standpoint of handling and feeding chemicals. The chemicals tested singly are listed in Table 35. In summary of this work, extremely high dosages of the cationics, Calgon ST-260 and Hercules 220 were effective in flocculation. The cost of treating wastewater at these dosages would have been economically prohibitive.

The anionic material found to be effective in single systems were Dow A-21 and Nalco 610. The dosage of these chemicals was in a range which was economically feasible. Costs of the single systems tested are given in Table 36.

In addition to organic flocculants tested, ferric chloride was tested and found active at an optimum dosage of 100 mg/1. However, even at this dosage the flocculation was not rapid and the ferric hydroxide flocs were voluminous in nature which would indicate poor settling under dynamic conditions.

Several cation-anion dual flocculant systems were attempted. A list of these are shown in Table 37. The purpose of this was to see if two chemicals could be used to flocculate the waste at a reduced cost. The only dual systems found which produced a floc large enough for sedimentation in the overloaded primary sedimentation tanks was ferric chloride with Nalco 675, ferric chlorie with Nalco 610, and ferric chloride with Dow A-23.

Table 35

Single Flocculant Evaluation

Chemical	Optimum Or Maximum Dosage (mg/l)	Results
1. Calgon ST-260	20	Medium, voluminous floc formed
2. Calgon 269	2	Poor flocculation
3. Nalco 607	20	Poor flocculation
4. Nalco 675	2	Poor flocculation
5. Nalco 610	20	Medium flow with some clarity
6. Nalco 603	40	No activity
7. Hercules 220	20	Large, dense floc formed
8. Dow A-21	4	Large, dense floc formed
9. Dow A-22	2	No activity
10. Dow A-23	2	No activity
11. Dow C-31	50	No activity
12. Dow C-32	50	No activity
13. Dow SA 116.1A	50	No activity
14. Dow SA 11881.F	50	No activity
15. Dow SA 1569	50	No activity
16. Dow SA 1767	40	No activity
17. Dow 1621.2	40	No activity
18. Dow N-11	2	No activity
19. Dow N-12	2	No activity
20. Dow N-17	2	No activity
21. $FeCl_3$ (anhydrous)	100	Medium voluminous floc with excellent clarity

Table 35
(Continued)

Chemical	Optimum Or Maximum Dosage (mg/1)	Results
22. General Mills* 162	35	No activity
23. General Mills 263	35	No activity
24. Polyethylene imine	50	Fine voluminous floc formed

* General Mills Inc., Kankakee, Illinois

Table 36

Single Flocculant Summary

Chemical	Price ($/lb.)	Optimum Dosage (mg/1)	Treatment Cost ($/MG)
1. $FeCl_3$ (anhydrous)	0.055	100	46
2. Calgon ST-260	1.75	20	290
3. Hercules 220	1.75	20	290
4. Dow A-21	1.00	4	33
5. Nalco 610	2.45	2*	41*

* Later determined to be 20 and 410

Table 37

Dual Flocculant Evaluation

	Chemical #1	Chemical #2	Results
1.	$FeCl_3$ (Anhydrous)	Dow A-21	No synergism
2.	$FeCl_3$ (Anhydrous)	Nalco 610*	No synergism*
3.	$FeCl_3$ (Anhydrous)	Nalco 675	Synergism suspected
4.	Calgon 260	Dow A-21	No synergism
5.	Hercules 220	Dow A-21	No synergism
6.	Calgon 260	Nalco 610	No synergism
7.	Hercules 220	Nalco 610	No synergism
8.	$FeCl_3$ (Anhydrous)	Iron Ore	No synergism
9.	$FeCl_3$ (Anhydrous)	Calgon 260	No synergism
10.	$FeCl_3$ (Anhydrous)	Reten 220	No synergism
11.	$FeCl_3$ (Anhydrous)	A-22	No synergism
12.	$FeCl_3$ (Anhydrous)	A-23	Synergism suspected
13.	Dow A-21	Iron Ore	No synergism

* Synergism was suspected until an error of concentration was discovered.

Tests were then made of the consistency of these systems with changes of waste during the day and night. Along with these tests several suspended solids determinations were made in order to obtain some estimates of suspended solids removals and to be able to compare the systems under further investigation. Suspended solids were taken from jar tests by withdrawing the liquid from 2 inches below the surface at a paddle speed of 10 rpm.

Table 38 illustrates the consistency of these tests with the time of day. Nalco 610's effectiveness and 1 and 2 mg/l in the single and dual system was due to a mistaking of concentration by the manufacturer. When the concentration was found to be too high by a factor of 10, testing of Nalco 610 was discontinued because of high costs. Three systems which remained technically and economically feasible were:

1. Dow A-21 alone,
2. A dual system of Nalco 675 and ferric chloride, and
3. A dual system of Dow A-23 and ferric chloride.

The suspended solids results in Table 38 confirm the previous visual observations. The results also confirm the voluminous nature of the ferric hydroxide floc and its resistance to sedimentation under dynamic conditions. When the ferric chloride treated waste was allowed to settle under static conditions, it showed the best overall results.

The results of the laboratory evaluations of the chemicals for treatment of combined waste are:

1. Dow A-21 was the most active, economical, and consistent of single chemical systems tested at dosages between 2 and 5 mg/l.

Table 38

Laboratory Results On Consistency Tests

Tests	Day	Time	Chemical	Dosage (mg/l)	Suspended Solids mg/l Degritted Raw	Control	Treated
1.	6/19/69	6:00 a.m.	Dow A-21	2.0	192	14[illegible]	53
2.	6/19/69	6:00 a.m.	$FeCl_3$*/Nalco 610	10/10**	192	164	47
3.	6/19/69	6:00 a.m.	$FeCl_3$*/Nalco 610	20/10**	192	164	49
4.	6/19/69	9:00 a.m.	Dow A-21	3.0	1111	769	560
5.	6/19/69	9:00 a.m.	Dow A-21	4.0	1111	769	311
6.	6/19/69	9:00 a.m.	Dow A-21	5/0	1111	769	204
7.	6/19/69	9:00 a.m.	$FeCl_3$*/Nalco 610	40/10**	1111	824	144
8.	6/19/69	9:00 a.m.	$FeCl_3$*/Nalco 610	50/10**	1111	824	172
9.	6/19/69	9:00 a.m.	$FeCl_3$*	50	1111	824	1051
10.	6/20/69	9:30 a.m.	Dow A-21	4.0	804	704	268
11.	6/20/69	9:30 a.m.	Nalco 610	2.5	804	692	824
12.	6/20/69	9:30 a.m.	$FeCl_3$*/Nalco 610	50/1	804	728	884

* Anhydrous
** Thought to be 1 mg/l at time of investigation

Table 38 (Continued)

Tests	Day	Time	Chemical	Dosage (mg/1)	Suspended Solids mg/1		
					Degritted Raw	Control	Treated
13.	6/20/69	10:40 a.m.	Dow A-21	4.0	1040	956	292
14.	6/20/69	10:40 a.m.	$FeCl_3$*/Dow A-21	40/3	1040	976	1028
15.	6/20/69	10:40 a.m.	$FeCl_3$*/Dow A-21	40/4	1040	976	580
16.	6/20/69	10:40 a.m.	$FeCl_3$*	100	1040	976	1276
17.	6/20/69	12:40 p.m.	Dow A-21	4.0	1200	1136	312
18.	6/20/69	12:40 p.m.	Dow A-21	5.0	1200	1136	252
19.	6/20/69	12:40 p.m.	$FeCl_3$*/Nalco 610	40/1	1200	1064	1220
20.	6/20/69	12:40 p.m.	$FeCl_3$*/Nalco 610	40/5	1200	1064	696
21.	6/20/69	12:40 p.m.	$FeCl_3$*/Nalco 610	40/10	1200	1064	140

* Anhydrous

** Thought to be 1 mg/l at time of investigation

2. There was a definite indication of synergism and increased performance over a single system in both dual systems, i.e., ferric chloride plus Nalco 675 and ferric chloride plus Dow A-23.

3. These systems consistently flocculated during waste changes with the time of day.

Some additional laboratory tests were run on order of addition of ferric chloride and the polyelectrolyte. The two polyelectrolytes (Dow A-23 and Nalco 675) which had indicated activity in the previous tests were used. Tests were made on the six place gang stirrer. Samples were run as follows.

1. A control sample which was stirred, but to which nothing was added,

2. A sample to which ferric chloride was added first followed after a five-minute interval by the polyelectrolyte.

3. A sample to which ferric chloride was added followed at a ten-minute interval by a polyelectrolyte,

4. A sample to which the polyelectrolyte was added first followed at a five-minute interval by ferric chloride.

5. A sample to which the polyelectrolyte was added first followed at a ten-minute interval by ferric chloride.

6. A sample to which the ferric chloride and polyelectrolyte were added at the same time.

Samples were also taken about 5 centimeters (2 inches) below the surface of the wastewater while it was being stirred at 10 rpm. Suspended solids determinations were made for each sample and also for the sample of the degritted waste. In all cases, 50 mg/l ferric chloride and 1.0 mg/l polyelectrolyte were used.

Some general observations were made for both of the polyelectrolytes. In those samples to which ferric chloride was added first a fine floc formed after a short time. When the polyelectrolyte was added a dense heavy floc slowly formed. This floc did not disappear on further stirring and began to settle as soon as stirring was slowed. There was not observable difference between samples having five and ten minute delays before addition of polyelectrolytes. In those samples to which the polyelectrolyte was added first there was no observable effect due to the additon of the polyelectrolyte. When ferric chloride was added last the floc built more slowly than where it was added first. Also, the floc did not become nearly as large or dense. In some trials a denser floc was formed in the sample having a ten minute waiting period before addition of ferric chloride, but this was not consistently true. In the sample to which ferric chloride and the polyelectrolyte were added at the same time a fairly large floc formed almost at once. When the chemicals were added at the same time the floc was long and filamentous. It continued to build up for a short time after the addition of chemicals and then started to break up. In some trials it broke up to the point where it was not much heavier than a ferric chloride floc. Other times a heavier floc would remain, but not as heavy as in the case where ferric chloride was added first followed by the polyelectroyte. The results of the tests run are shown in Tables 39 and 40. These tests indicate the best order of addition of the dual system was ferric chloride first followed after a 5 to 10 minute period by the polyelectrolyte.

Table 39

Order Of Addition Tests
A-23 - $FeCl_3$

Suspended Solids mg/l

Trial	Raw Degritted	Control	$FeCl_3$ Then A-23 At 5 Min.	$FeCl_3$ Then A-23 At 10 Min.	A-23 Then $FeCl_3$ At 5 Min.	A-23 Then $FeCl_3$ At 10 Min.	A-23 and $FeCl_3$ Same Time
1	1268	808	68	88	200	168	284
2	1124	600	116	112	212	196	176
3	892	740	120	116	220	296	256
4	844	604	120	128	212	196	400
5	664	556	128	196	216	228	292
6	660	508	148	116	320	236	436
7	1108	760	132	296	420	256	632
8	1136	720	132	164	456	272	544
9	1976	1348	540	244	400	540	672
10	1428	996	328	252	468	356	532
Ave.	1110	764	183	171	312	274	422

Table 40

Order Of Addition Tests
675 - $FeCl_3$

Suspended Solids mg/l

Trial	Degritted	Control	$FeCl_3$ Then 675 At 5 Min.	$FeCl_3$ Then 675 At 10 Min.	675 Then $FeCl_3$ At 5 Min.	675 Then $FeCl_3$ At 10 Min.	675 and $FeCl_3$ Same Time
1	792	448	80	60	148	152	172
2	544	302	68	108	172	196	256
3	940	564	60	88	176	164	188
4	824	568	56	88	308	228	264
5	572	548	96	192	324	204	264
6	372	216	52	60	176	124	156
7	1104	468	72	52	184	204	256
8	1976	808	128	72	388	196	468
9	1164	1200	108	92	316	216	376
10	1276	596	120	104	292	108	492
Ave.	956	581	84	92	248	159	289

Some laboratory tests were run using a waste ferric chloride material obtained from the Buckbee Mears Manufacturing Company of St. Paul, Minnesota. The results of these tests indicated that the waste ferric chloride material was slightly more active than the bulk (anhydrous) ferric chloride. On further investigation a considerable price difference was found between the waste ferric chloride and the bulk ferric chloride with the bulk ferric chloride being several times more costly than waste ferric chloride. The anhydrous ferric chloride was an industrial grade purchased from a local chemical company in 61 kilogram (135 pound) drums.

Ferric chloride waste solution was the byproduct of the Buckbee Mears Manufacturing Company. The ferric chloride is used during the manufacture of steel sheets to make television screens, electric shaver heads, steel sieves, and other items where small uniform high-density holes in steel plate are needed.

The ferric chloride is regenerated from time to time by the addition of hydrochloric acid and chlorine. Eventually some of it is wasted. Specific gravity tests indicated a 45% concentration of ferric chloride An analysis was performed by a consulting laboratory which verified the ferric chloride content to be approximately 45% with small quantities of other metals present as indicated in the analysis.

SECTION VIII

PLANT EVALUATION OF NON-PATENTED SYSTEMS

Personnel from the Robert S. Kerr Environmental Research Laboratory returned to the plant in July 1969 to set up plant-scale tests to determine if sufficient suspended solids and BOD removal could be obtained in the primary clarification portions of the plant to warrant more extensive study of the removals. If so, this would be accomplished in the primary portion of the plant and eventually more extensive studies of overall efficiency could be accomplished through the entire plant.

The three flocculating systems which were evaluated briefly on the primary portion of the plant were:

1. Dow A-21 at 2 to 5 mg/1,
2. A dual system of 20 to 60 mg/1 of ferric chloride plus .75 to 1.4 mg/1 of Nalco 675, and
3. A dual system of 30 to 50 mg/1 of ferric chloride plus .75 to 1.3 mg/1 of A-23.

CONTROL CHECK

The first day of the week was used to make polymer solutions, calibrate pumps, and prepare other details necessary for chemical feed. This day was therefore used for an additional control period to illustrate the equality of the two primary tanks. The results of this control day are illustrated in Table 41. The results of this control day indicated no significant difference between the test and control tanks as shown by the results of the t-test in Table 46.

Table 41

Control Day - No Chemicals Added
July 14-15, 1969

		Suspended Solids mg/l	
Time	Influent	Test	Control
8 a.m.	604	64	68
9 a.m.	1228	140	196
10 a.m.	1236	256	232
11 a.m.	884	228	260
12 Noon	1120	272	276
1 p.m.	776	300	296
2 p.m.	736	308	-
3 p.m.	1364	272	272
5 p.m.	728	436	320
6 p.m.	608	300	404
7 p.m.	740	300	280
8 p.m.	536	272	264
10 p.m.	288	272	156
12 Mid.	336	612	408
2 a.m.	252	112	88
4 a.m.	176	80	76
6 a.m.	244	48	76
24 hour composite	744	232	224

SINGLE SYSTEM

The single system of Dow A-21 was tested for 48 hours on July 15 and 16. The results of these tests (Table 42) indicated increase in removal of suspended solids in test tank versus the control tank. The composite sample confirmed this showing, 208 mg/l of suspended solids in the control tank compared to 136 mg/l in the test tank.

The effluent from the test tank treated with Dow A-21 appeared extremely turbid and visually appeared approximately the same as the effluent from the control tank.

The major visual difference between the control and test tanks was the massive flocs formed in the test tank, BOD results were also obtained on a few selected samples and the data indicated very small differences in BOD removals.

THEORY OF EFFECTIVENESS OF THE DUAL SYSTEM

Colloidal particles are kept in suspension in the wastewater because of their small size. These particles are covered with a surface charge which causes them to repel each other thereby preventing the forming of larger particles which would settle out of suspension. When multivalent ferric ion is added in solution, it neutralizes the surface charge on the colloidal particles and allows them to merge. Mixing of these small particles then causes the larger particles to build, as the natural cohesive forces come into play, and results in coagulation of a floc. The cohesive forces holding the floc together are relatively weak and shearing of the floc occurs before it can grow very large. The addition of ferric chloride alone results in a fine floc which will not settle out in the dynamic situation of a sedimentation tank but instead passes over the weir. The suspended solids test measures the amount of solids retained on a filter when a sample of wastewater is passed through. When a wastewater

Table 42

Purifloc A-21 (Dow Chemical Company)
July 15-16, 1969

Time	Flow (mgd)	Purifloc A-21 Dosage mg/l	Suspended Solids mg/l Influent	Test	Control
8 a.m.	4.9	2.25	548	96	92
9 a.m.	6.6	2.60	832	180	196
10 a.m.	6.6	2.85	1092	172	212
11 a.m.	3.9	3.30	1180	212	224
12 Noon	7.9	4.30	1276	212	224
1 p.m.	7.7	5.00	1172	184	276
2 p.m.	7.7	4.20	1014	196	272
3 p.m.	7.9	4.00	840	260	332
4 p.m.	6.1	5.00	696	232	304
5 p.m.	5.8	4.00	796	248	340
6 p.m.	5.5	2.40	544	224	460
7 p.m.	5.5	4.00	508	232	272
8 p.m.	4.4	3.20	452	172	264
10 p.m.	6.6	3.00	620	128	192
12 Mid.	4.4	2.30	312	76	-
2 a.m.	4.2	2.00	316	76	136
4 a.m.	3.9	2.00	252	72/80	76
6 a.m.	5.0	2.00	240	54	108

Table 42 (Continued)

Purifloc A-21 (Dow Chemical Company)
July 16-17, 1969

Time	Flow (mgd)	Purifloc A-21 Dosage mg/l	Suspended Solids mg/l Influent	Test	Control
8 a.m.	6.1	3.00	500	100	72
9 a.m.	7.1	2.10	824	132	168
10 a.m.	7.2	3.70	1108	180/184*	236/232*
11 a.m.	7.2	4.00	1000	224	236
12 Noon	7.4	3.80	840	208	240
1 p.m.	7.4	4.00	916	192/196*	248
2 p.m.	6.9	3.20	1004	208	256
3 p.m.	7.4	4.00	1048	200	284
6 p.m.	5.7	4.00	680	212	248
7 p.m.	6.6	3.00	780	196/200*	224
8 p.m.	6.1	3.60	512	160	264
10 p.m.	5.3	3.00	364	144	104
12 Midn.	4.2	4.50	204	80	120
2 a.m.	3.9	4.50	228	56	116
4 a.m.	3.7	5.00	204	60/72*	88
6 a.m.	3.7	5.00	212	40	96
Mean					
July 15-16, 1969			705	168	234
July 16-17, 1969			647	150	176
Composite					
July 15-16, 1969			572	156	244
July 16-17, 1969			572	136	208

* Duplicate analysis

sample not treated with ferric chloride is passed through the filter some of the larger colloidal particles are entrained, but the smaller colloidal particles pass through. If ferric chloride has been added to the wastewater some smaller colloidal particles are coagulated and thus retained on the filter in a suspended solids test. Since no additional solids have been settled out in sedimentation tank, the amount of suspended solids are actually increased because of the coagulated small colloidal particles. Since there is no actual increase of organic solids, the BOD does not substantially change.

When the organic polyelectrolyte is added to the wastewater after the addition of ferric chloride, the long molecules with their localized charge hook into the fine ferric chloride floc causing bridging between the fine particles. This results in the formation of a floc which is large and dense enough to settle out and still strong enough to resist the shearing action which occurs in the wastewater. This is what makes the dual systems tested effective. The addition of the polyelectrolyte alone is not effective since it does not have sufficient capacity to neutralize all the surface charge on the realtively dense, fine colloidal solids found in the stronger packinghouse waste. It is therefore necessary to precede the polyelectrolyte by a flocculating aid such as ferric chloride in a dual system.

DUAL SYSTEM

On July 17 of the test week a dual system of ferric chloride and Nalco 675 was attempted. It was felt that it would be desirable to add the polyelectrolyte at a point in the flow approximately 10 to 15 minutes after the addition of the ferric chloride. It was therefore necessary to construct a distribution pipe to feed the polyelectrolyte approximately 1/3 to 1/2 the distance from the entrance into the flocculation tank. The point of addition was determined by adding a dye tracer to the influent and tracing the dry through the flocculation tank.

The ferric chloride dosage was held at approximately 50 mg/l from 8 AM to 8 PM and 30 mg/l from 8 PM to 8AM. The polyelectrolyte dosage was held at 1.0 mg/l from 8 AM to 8 PM and 0.75 mg/l from 8 PM to 8 AM.

In comparing this dual system with the single polymer system previously used it appeared from the data that greater and more consistent removals of solids and BOD were obtained with the dual system of ferric chloride and Nalco 675. The composite sample was reduced from 252 mg/l of suspended solids in the control tank effluent to 132 mg/l in the test tank effluent. In addition, the BOD in the composite effluent in the control tank was 830 mg/l compared to 545 mg/l in the test tank. The results of this day's run are shown in Table 43.

On July 18 the dual system of ferric chloride and Dow A-23 was run. The dosage level of chemicals was maintained at the same rate as on the previous day. The results of this day's test was shown in Table 44.

The composite samples indicated suspended solids reduction of from 200 mg/l in the control tank to 96 mg/l in the test tank with a corresponding BOD reduction from 680 mg/l in the composite effluent of the control tank to 96 mg/l in the test tank with a corresponding BOD reduction from 680 mg/l in the composite effluent of the control tank to 493 mg/l in the test tank.

A statistical evaluation of this one week run is given in Table 45. The following conclusions were indicated:

1. The single polymer Dow A-21 achieved a significant difference in removals of suspended solids in the primary sedimentation portion of the plant. In comparision to the dual systems attempted, the single polymer system appeared inferior. The Dow Chemical Company announced that the production of A-21 had been discontinued and there were no plans for restarting production of this chemical.

Table 43

FeCl$_3$ And Nalcolyte 675 (Nalco Chemical Company)
July 17-18, 1969

		Chemicals		Suspended Solids mg/l			BOD mg/l		
	Flow	FeCl$_3$	675						
Time	(mgd)	mg/l	mg/l	Influent	Test	Control	Influent	Test	Control
8 a.m.	6.1	0	0	536	72	92	--	--	--
9 a.m.	7.4	43	.94	992	132	160	--	--	--
10 a.m.	6.1	40	1.00	1196	120/108	228/232	--	680	800
11 a.m.	6.1	41	.95	976	148	216	--	630	715
12 Noon	6.3	45	.95	868	176	248	--	--	--
1 p.m.	6.0	40	.90	1044	140/104	228	--	--	--
2 p.m.	6.6	43	.85	1188	152	248	--	600	770
3 p.m.	6.1	57	1.10	848	284	360	--	--	--
4 p.m.	6.1	50	1.00	1116	228	324	--	643	740
5 p.m.	5.9	46	1.20	784	256/228	340	--	--	--
6 p.m.	6.2	52	.74	620	172	392	--	560	805
7 p.m.	5.5	50	1.40	1124	176	296	--	--	--
8 p.m.	4.6	50	1.20	284	120	196	--	360	470

Table 43 (Continued)

FeCl$_3$ And Nalcolyte 675 (Nalco Chemical Company)
July 17-18, 1969

				Suspended Solids mg/1			BOD mg/1		
Time	Flow mgd	FeCl$_3$ mg/1	675 mg/1	Influent	Test	Control	Influent	Test	Control
9 p.m.	5.8	20	.75	324	80	160	--	--	--
10 p.m.	4.4	30	.38	280	108	136	--	--	--
11 p.m.	4.2	17	.57	312	52	168/152	--	--	--
12 Mid.	-	--	--	-	-	--	--	--	--
1 a.m.	-	--	--	224	60	108	--	--	--
6 a.m.	-	--	--	204	72	84	--	--	--
Mean				718	139	221			

Table 44

$FeCl_3$ And Purifloc A-23 (Dow Chemical Company)
July 18-19, 1969

		Chemicals		Suspended Solids mg/1			BOD mg/1		
Time	Flow mgd	$FeCl_3$ mg/1	A-23 mg/1	Influent	Test	Control	Influent	Test	Control
8 a.m.	5.7	44	1.1	--	--	--	--	--	--
9 a.m.	6.6	35	1.3	936	116	268	--	--	--
10 a.m.	6.0	29	1.0	1008	160/140	208/200	--	733	858
11 a.m.	5.7	57	1.0	852	140	220	--	--	--
12 Noon	6.2	49	1.0	892	116	224	--	453	795
1 p.m.	5.4	42	1.0	572	172/152	264	--	--	--
2 p.m.	6.3	50	1.0	1028	108	--	--	468	685
3 p.m.	6.3	59	1.1	908	92	332	--	--	--
4 p.m.	-	-	-	764	220	396	--	523	798
5 p.m.	6.5	45	.8	700	256/252	284	--	--	--
6 p.m.	6.1	47	.8	576	200	504	--	686	962
7 p.m.	5.0	27	1.0	396	120	268	--	--	--
8 p.m.	4.4	30	1.2	308	72	248	--	430	612
9 p.m.	4.1	0	1.2	420	68/64	172	--	--	--

Table 44 (Continued)

$FeCl_3$ And Purifloc A-23 (Dow Chemical Company)
July 18-19, 1969

		Chemicals		Suspended Solids				BOD mg/l	
Time	Flow mgd	$FeCl_3$ mg/l	A-23 mg/l	Influent	Test	Control	Influent	Test	Control
10 p.m.	5.0	36	.85	260	104	144	--	295	351
11 p.m.	3.4	26	.85	248	72	252	--	--	--
12 Mid.	3.4	33	.85	120	52	112	--	--	--
1 a.m.	3.4	13	1.10	220	48/48	96	--	--	--
2 a.m.	3.4	20	1.10	280	36	88	--	--	--
3 a.m.	3.4	20	.85	216	44	92	--	--	--
4 a.m.	3.4	20	.68	216	40	100	--	--	--
5 a.m.	3.4	20	.85	176	40/48	76	--	--	--
6 a.m.	3.4	16	.85	216	44	52	--	--	--
7 a.m.	3.4	27	1.10	180	36	76	--	--	--
8 a.m.	3.4	20	--	232	32	76	--	--	--
Mean	-	--	--	488	99	197	--	--	--
24 hour composite		--	--	536	96	200	1160	493	680

Table 45

Statistical Analysis Of One Week Run

Date 1969	Chemical Dosage	Sus. Solids Ave. Diff. Test Less Control	Standard Deviation In Ave. Diff.	t	# Of Paired Observations	
July 14	No Treatment	18.25	73.32	0.996	17	*
July 15	2-5 mg/l A-21	-53.44	61.49	-3.687	17	**
July 16	2-5 mg/l A-21	-37.12	35.95	-4.131	17	***
July 17	.75 - 1.3 mg/l 675 +20 - 57 mg/l $FeCl_3$	-83.47	47.72	-7.624	16	***
July 18	.75 - 1.3 mg/l A-23 +30 - 50 mg/l $FeCl_3$	-102.83	75.82	-6.644	16	***
Comp.		-96.00	20.65	-9.295	4	***

* Indicates not significant
** Indicates $p<.01$
*** Indicates $p<.001$

2. The dual system of ferric chloride and organic polyelectrolyte tested significantly incresed removals of suspended solids and BOD in primary sedimentation portions of the plant.

3. The two dual systems tested were not judged different in removal efficiencies.

SECTION IX

ADDITIONAL DISCUSSION OF NON-PATENTED SYSTEMS

ADDITIONAL PLANT TESTS

In the year following these initial tests a considerable amount of additional plant scale testing was done.

The year of testing was divided on December 1, 1969, because this was when Swift & Company discontinued slaughtering operations at their South St. Paul plant. This reduced the packing plant wastes coming into the plant by about half and considerably changed the characteristics of the wastewater. Testing results, however, were similar although not directly comparable for the two parts of the year. In the part of this year before Swift & Company discontinued slaughtering operations the following tests were run:

1. A dual system: ferric chloride (anhydrous) followed by Dow A-23

2. A dual system: ferric chloride waste material (Buckbee Mears, See Appendix D) followed by Dow A-23

3. A dual system: ferric choride (anhydrous) follwed by Nalco 675

4. A dual system: ferric chloride waste material (Buckbee Mears) followed by Nalco 675

5. Variations in the ferric chloride dosage in an attempt to optimize the best dosage which could be achieved.

6. The use of a ferric chloride (anhydrous) with Nalco D-2339. This polyelectrolyte had proved to be active when used with ferric chloride in laboratory tests.

7. The addition of ferric chloride at a dosage of 50 mg/l.

8. The addition of ferric chloride at a dosage of 100 mg/l.

9. Tests on packinghouse waste only with ferric chloride (anhydrous) and Nalco 675.

Tests run after Swift and Company discontinued slaughtering operations were:

1. Tests on separated "domestic" waste. These wastes were predominantly a mixture of wastewater from the residential area of the City of South St. Paul and wastes from the stockyards. Small quantities of packinghouse wastes were in this stream, but these were not substantial.

2. Some tests were run using ferric chloride and Nalco 675 on the waste as received after the reduction in volume of packing industries. These tests were run on the combined wastewater and on both the separated industrial and domestic wastewater.

3. A one month test was run on the entire plant flow of combined wastewater using ferric chloride and Nalco 675. Samples were taken throughout the plant and an evaluation made on the effectiveness of this dual system of chemical treatment on overall plant efficiency.

4. A control month with no chemicals added.

Tests 1 through 4 were conducted in the following order:

1. Anhydrous ferric chloride followed by Dow A-23
2. Buckbee Mears ferric chloride followed by Dow A-23
3. Pennsalt ferric chloride followed by Nalco 675, and
4. Buckbee Mears ferric chloride followed by Nalco 675.

The ferric chloride was added to the wastewater at a point just after it was split between the test and control tanks. The wastewater was then passed through the mixing chamber and into the mechanical flocculators. The polyelectrolyte was added to the waste approximately 10 to 15 minutes after the addition of ferric chloride in the mechanical flocculators.

Measurements were taken of the water depth of the flow in the parshall flume meters several times a week during these tests and all subsequent tests to assure that both meters were working accurately and that the stream of wastewater was being divided equally between the test and control tanks.

Samples were taken at the influent to the test system and at the effluent to the test and control tanks. Samples were taken hourly on a 24 hour basis from which a composite sample was prepared. Grab samples were taken every two hours during the day from 8 AM to 8 PM and every four hours at night. Suspended solids were run on each of the grab samples and BOD's were run on four sets of the grab samples taken at 10 AM, 12 Noon, 2 PM, and 4 AM. The summary of the results of the plant scale tests are given in Table 46.

OBSERVATIONS FROM PLANT SCALE TESTS

All four tests showed a significant reduction in suspended solids and BOD for the test tank versus the control tank. This was true of both the grab samples and the composite samples. Since a much larger number of grab samples were available for analysis, the results of the tests on grab samples are more reliable. The results are given in Table 46. Statistical analysis for significance of difference in suspended solids in the effluents of the test and control tank indicate a significant difference for all four tests. The results of this statistical analysis are also indicated in Table 46.

Table 46

Summary Of Test Data

	Suspended Solids mg/1							BOD mg/1			
Chemicals	Inf.	Test	% Red.	Control	% Red.	Test - Control	Inf.	Test	% Red.	Control	% Red.
Grab Sample Average											
A-23 $FeCl_3$ Anhydrous	621	113	81.8	174	72.0	61	1322	549	58.5	663	49.8
A-23 $FeCl_3$ Waste (As Liquid)	552	117	78.8	162	70.7	45	1244	604	51.5	707	43.3
675 $FeCl_3$ Anhydrous	644	120	81.4	211	67.2	91	1338	555	58.5	691	48.3
675 $FeCl_3$ Waste (As $FeCl_3$)	803	106	86.8	202	74.9	96	1272	632	50.3	772	39.4
Composite Samples											
A-23 $FeCl_3$ Anhydrous	631	106	83.2	168	73.3	65	985	451	54.2	536	45.5
A-23 $FeCl_3$ Waste (As Liquid)	525	131	75.0	147	72.0	16	814	514	36.8	584	28.2
675 $FeCl_3$ Anhydrous	635	130	79.5	183	71.2	53	952	486	48.9	618	35.2
675 $FeCl_3$ Waste (As $FeCl_3$)	875	118	86.5	220	74.9	102	1178	519	56.0	584	50.3

Table 46 (Continued)

Comparison Of Test And Control

Test	Sus. Solids Average Diff. Test- Control	Std. Deviation Average Diff.	t	No. Of Paired Observations	p
A-23 And Anhydrous $FeCl_3$	-61	31.4	-11.39	34	$<.01$
A-23 And Waste $FeCl_3$*	-45	47.6	- 5.55	34	$<.01$
675 And Anhydrous $FeCl_3$	-91	65.1	- 8.27	35	$<.01$
675 And Waste $FeCl_3$**	-96	51.8	- 9.45	26	$<.01$

Comparison Of Tests***

	Test	Mean	Variance	No. Of Samples	t	p
A-23 and Anhydrous $FeCl_3$ vs.	1st	113.12	4033.50	34	-0.498	.62
675 and Anhydrous $FeCl_3$	2nd	120.74	3811.54	35		
A-23 and Anhydrous $FeCl_3$ vs.	1st	113.12	4033.50	34	-0.544	.59
A-23 and Waste $FeCl_3$	2nd	121.23	3127.65	31		
675 and Anhydrous $FeCl_3$ vs.	1st	120.74	3811.54	35	0.820	.41
675 and Waste $FeCl_3$	2nd	108.32	2511.89	25		

* Added as mg/l of liquid
** Added as mg/l of solid
*** Comparison of means of effluent concentrations were made rather than difference in concentration because of more similiar populations

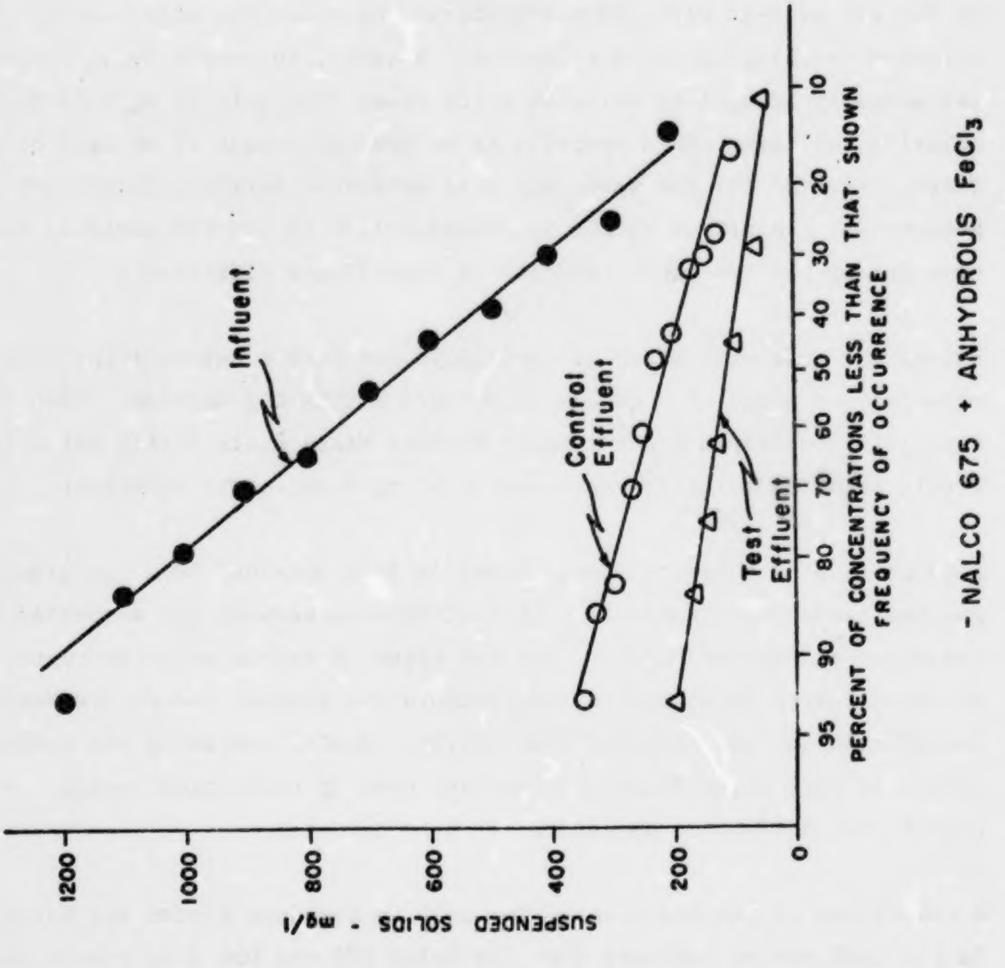
Figures 7 through 10 indicate the suspended solids concentration for the four tests using frequency distribution curves. These curves serve to illustrate the significance of the data. In all four cases the suspended solids in the effluent of the test tank were significantly less than those in the effluent of the control tank.

When results of the test A-23 and anhydrous ferric chloride are compared to the use of A-23 with the waste ferric chloride, the anhydrous ferric chloride was slightly more efficient. However, the waste ferric chloride was added as 50 mg/l of solution which meant that only 22 mg/l of ferric chloride was being added compared to an average dosage of 40 mg/l of ferric chloride for the weeks run when anhydrous ferric chloride was used. Statistical comparison of the suspended solids in the effluents of the test tank during the two tests indicate no significant difference.

During the test with Nalco 675 and anhydrous ferric chloride the ferric chloride was added at a dosage of 50 mg/l during the daytime. When the same polyelectrolyte was run using Buckbee Mears waste ferric chloride, the ferric chloride solution was added at 50 mg/l of ferric chloride.

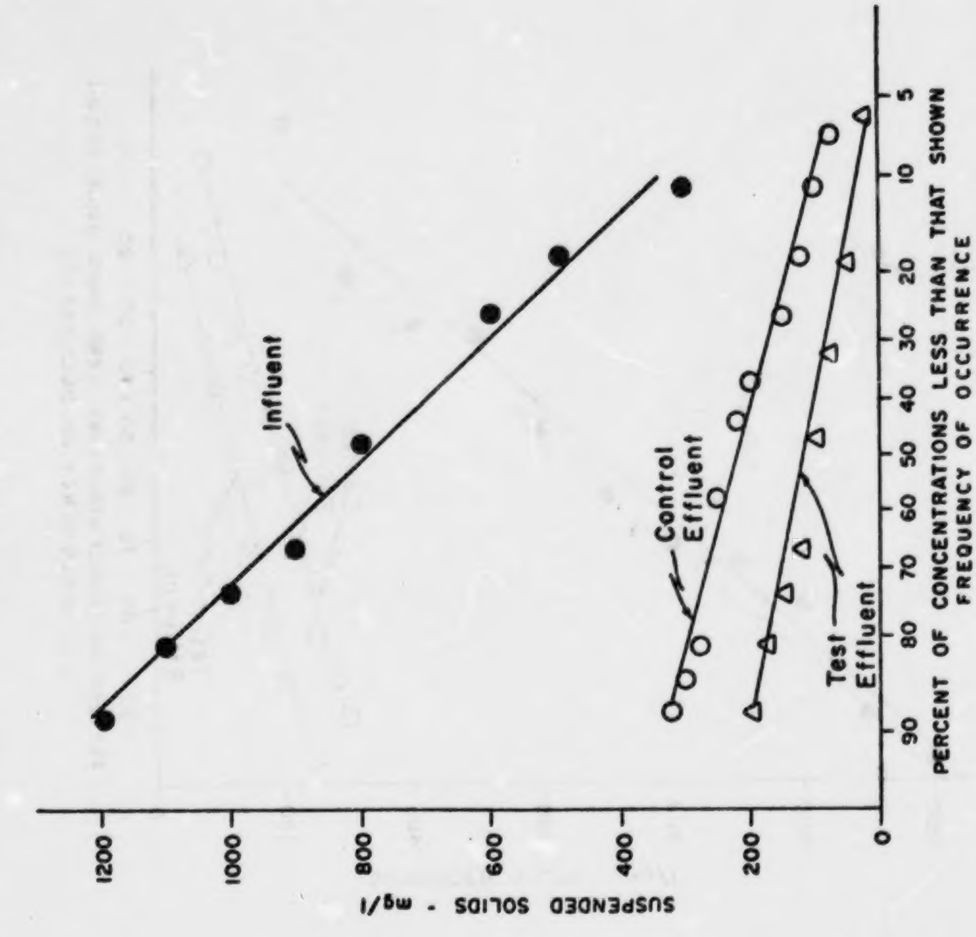
A comparison of these two tests based on data obtained from the grab samples taken would indicate little difference between the suspended solids reduction and BOD reduction. The two types of ferric chloride appear to be equivalently effective in the flocculation process though the waste ferric chloride was somewhat less costly. Again, comparing the suspended solids in just the effluent of the test tank by statistical means, no significant difference appeared.

A comparison of the tests using Dow A-23 in the dual system and Nalco 675 in the dual system indicate that the Nalco 675 and Dow A-23 were equivalent. The daytime dosage of ferric chloride in the dual system using Nalco 675



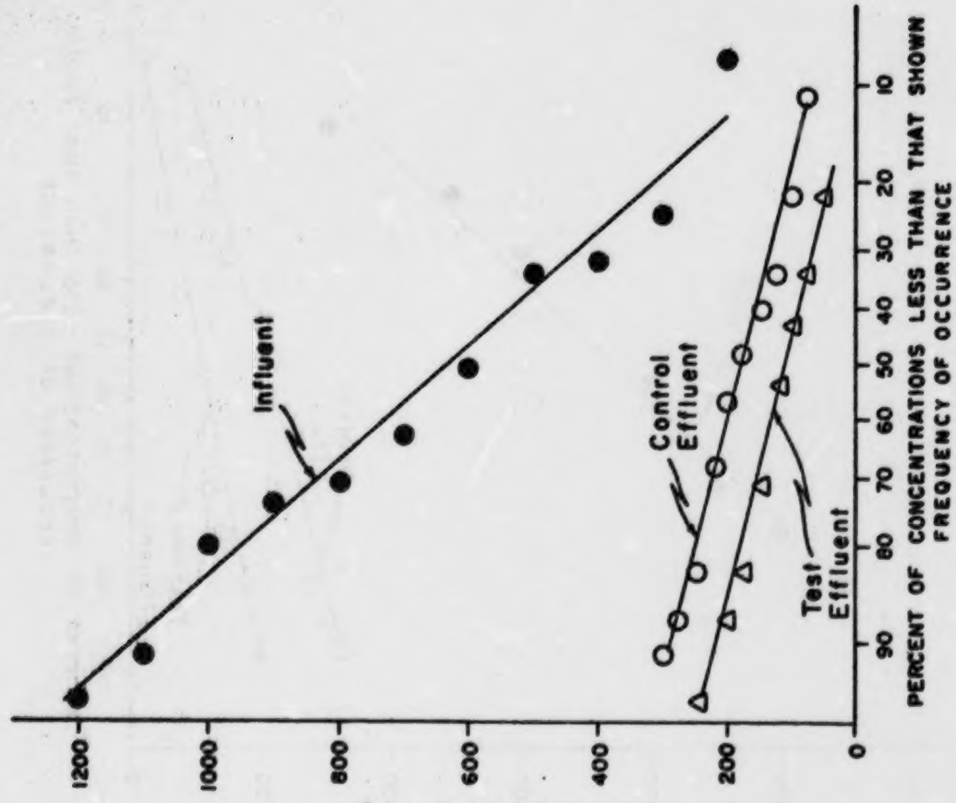
- NALCO 675 + ANHYDROUS $FeCl_3$

FIGURE - 7



- NALCO 675 + WASTE $FeCl_3$

FIGURE - 8



- DOW A23 + ANHYDROUS $FeCl_3$

FIGURE - 9

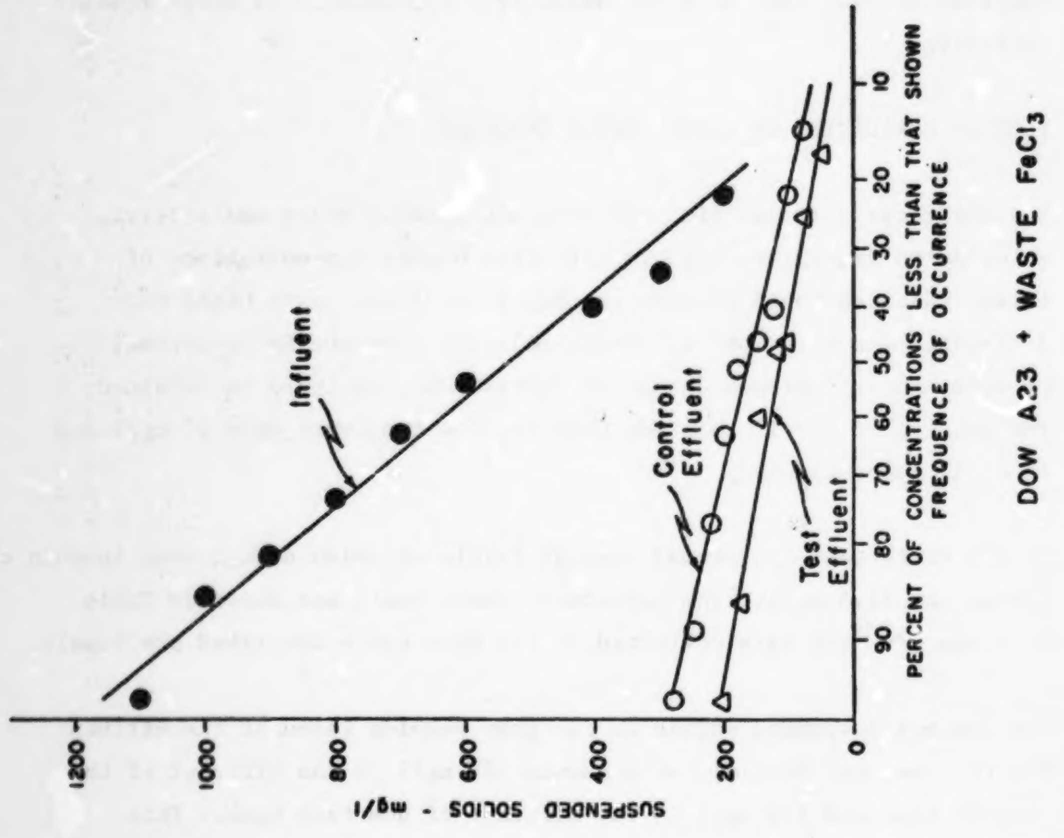

DOW A23 + WASTE $FeCl_3$
SUSPENDED SOLIDS - mg/l
1200
1000
800
600
400
200
0
PERCENT OF CONCENTRATIONS LESS THAN THAT SHOWN FREQUENCE OF OCCURRENCE
90
80
70
60
50
40
30
20
10
Influent
Control Effluent
Test Effluent

FIGURE - 10

showed an average of about 50 mg/l while ferric chloride dosage with A-23 was 40 mg/l. Statistical analysis of suspended solids in the effluent of the test tank during the two tests indiactes no significant difference.

The conclusions drawn from these tests indicate little difference in the effectivness in the two types of ferric chloride in the dual systems tested. Also, from a statistical evaluation of the data the two polyelectrolytes (Dow A-23 and Nalco 675) appeared to be about equally effective.

FURTHER EVALUATION OF WASTE FERRIC CHLORIDE

Further tests were run with Dow A-23 and Buckbee Mears waste ferric chloride to determine just how effective higher concentrations of ferric chloride would be with the Dow A-23. Also, tests using two different concentrations of ferric chloride were run in an attempt to determine if optimum dosage of ferric chloride could be obtained. The dosages of ferric chloride used for the two tests were 50 mg/l and 40 mg/l, respectively.

In the first test the actual average ferric chloride dosage used in this dual system was 49.3 mg/l. The results of these tests are shown in Table 47 along with the data collected in the four tests described previously.

The average suspended solids in the grab samples taken of the effluent for the test and control tanks showed 235 mg/l in the effluent of the control tank and 129 mg/l in the effluent of the test tank. This is comparable to the data collected for the previously described tests run using the dual system of Nalco 675 and ferric chloride at an actual average dosage of 46.9 mg/l for the test period. Statistical analysis comparing the data of the effluents of the dual systems of ferric chloride and Nalco 675 and ferric chloride and Dow A-23 verified there was no significant difference in the effectiveness of these polyelectrolytes.

Table 47

Summary Of Test Data

Chemicals	$FeCl_3$ Ave. Daytime Dosage	Sus. Solids mg/l Inf.	Sus. Solids mg/l Test	Sus. Solids mg/l Cont.	Test Less Control	BOD mg/l Inf.	BOD mg/l Test	BOD mg/l Control	BOD mg/l Diff.
A-23/Anhydrous $FeCl_3$	37.1	621	113	174	61	1322	549	663	114
A-23/Waste $FeCl_3$	19.1	552	117	162	45	1244	604	707	103
675/Anhydrous $FeCl_3$	45.4	644	120	211	91	1338	555	691	136
675/Waste $FeCl_3$	46.9	803	106	202	96	1272	632	772	140
A-23/Waste $FeCl_3$	49.3	744	129	235	106	1606	669	869	200
A-23/Waste $FeCl_3$	38.0	754	137	230	93	1481	650	852	202
D-2339/Anhydrous $FeCl_3$	61.2	1180*	159	245	86	--	-	-	-

Table 47 (Continued)

Comparison Of Test And Control

Test	Sus. Solids Ave. Diff. Test Less Control	Standard Deviation In Ave. Diff.	t	# Of Paired Observations	p
A-23 and Anhydrous $FeCl_3$	-61	±31.4	-11.39	34	.01
A-23 and Waste $FeCl_3$	-45	±47.7	- 5.55	34	.01
675 and Anhydrous $FeCl_3$	-91	±65.1	- 8.27	35	.01
675 and Waste $FeCl_3$	-96	±52.2	- 9.45	25	.01
A-23 and Waste $FeCl_3$	-106	±85.7	- 6.70	49	.01
A-23 and Waste $FeCl_3$	-93	±71.1	- 7.45	38	.01
D-2339 and Anhydrous $FeCl_3$	-86	±72.8	- 7.68	42	.01

The second test run was an attempt to optimize the dosage of ferric chloride and an attempt was made to hold the daytime dosage at 40 mg/l of ferric chloride with the nighttime dosage at 20 mg/l. The actual average daytime ferric chloride dosage was 38.0 mg/l The average suspended solids for the grab samples taken at the effluent of the control tank was 230 mg/l while the effluent of the test tank had a suspended solids of 137 mg/l. The BOD of the control and test tank effluent was 869 mg/l and 669 mg/l. respectively.

These results when compared to the other tests of the dual system of Dow A-23 and waste ferric chloride indicated that the dosage did not tend to optimize but rather the effectiveness of flocculation of the system increased with increased dosage of ferric chloride. This is illustrated by the average difference in suspended solids obtained from the control minus the test tank as compared with the three dosages of the waste ferric chloride used with Dow A-21. This is as follows:

Ferric Chloride Dosage	Suspended Solids Control-Test
19.1 mg/l	45 mg/l
38.0 mg/l	93 mg/l
49.3 mg/l	106 mg/l

TESTING NEW DEVELOPMENT PRODUCT

Nalco Chemical Company had a chemical which was thought might be more effective than Nalco 675 and slightly less costly. Nalco's field representatives were given an opportunity to demonstrate the effectiveness of the new product in the laboratory. The product was D-2339, and while it had a development number, it was in full production at the time the test was made but had not yet been assigned a product number.

The result of the laboratory tests was good. It appeared to be slightly more active than the Nalco 675. On the basis of these results it was decided to give this polyelectrolyte a one-week trial on a plant scale.

The polyelectrolyte was added at an estimated dosage of 1.0 mg/l from 8 AM to 10 PM and at a dosage of 0.75 mg/l from 10 PM to 8 AM. It was added to the flocculating chambers as had been done in previous tests. The ferric chloride used was anhydrous ferric chloride. The dosage was 61.2 mg/l from 8 AM to 10 PM. The night time dosage was about 35 mg/l. The results of this test are shown in Table 47. The average suspended solids run on grab samples was 245 mg/l for the control tank and 159 mg/l for the test tank. BOD's were not run on samples taken during this week. The results of suspended solids, however, did indicate a substantial difference between the test and control tanks. The results obtained in suspended solids reductions did not show a large difference from those obtained using Nalco 675 or Dow A-23. The price of the polyelectrolyte D-2339 was 5 to 15% less than Nalco 675 depending upon the quantity purchased. Since the ferric chloride represented about two-thirds of the chemical costs, the overall reduction of the chemical cost by the use of D-2339 compared to Nalco 675 would be in the order of 3%. This percentage would be further reduced when labor costs and equipment costs were taken into consideration.

PLANT EVALUATION OF FERRIC CHLORIDE ALONE

In order to determine how much the polyelectrolytes being run in the dual systems were contributing to the reduction of suspended solids, two plant scale tests were run in which only ferric chloride was added with no polyelectrolytes. The estimated dosage of ferric chloride was 50 mg/l in one test and 100 mg/l in the other.

In the first test the average actual dosage of ferric chloride fed was 47.6 mg/l. The ferric chloride formed a fine floc as was observable in previous laboratory and plant tests. But, with no organic polyelectrolyte to further flocculate this fine floc it was carried through the tank and over the weirs. The floc was readily observable in the test tank effluent as it flowed over the weir and as settleable solids tests in the imhoff cone test. It was also reflected in suspended solids tests run on grab samples.

The suspended solids in the effluent of the test tank were actually higher than those in the effluent of the control tank as indicated by the average of suspended solids run on grab samples. This was also the result in the average of the composite samples. The effluents of the two tanks showed no significant difference in BOD reduction between the two tanks. This was true for both the grab samples and the composite samples.

In the second test the actual average dosage of ferric chloride was 98.4 mg/l. Again a fine floc could be observed passing over the weirs of the test tank while none was observed passing over the weirs of the control tank. The suspended solids in the effluent of the test tank were again higher than the suspended solids in the control tank. The BOD in the effluent of the two tanks was not significantly different. The results of the tests are shown in Table 48. The data is graphically illustrated in Figures 11 and 12. These figures plot the frequency distribution of the suspended solids analysis for each of the two tests using 50 mg/l and 100 mg/l of ferric chloride, respectively. As indicated for samples having concentrations of over 200 mg/l of suspended solids, the test tank effluent had a higher suspended solids concentration than did the control tank. The results confirmed the explanation for the effectiveness of the dual system of ferric chloride plus a polyelectrolyte.

Table 48

$FeCl_3$ Only

Grab Samples

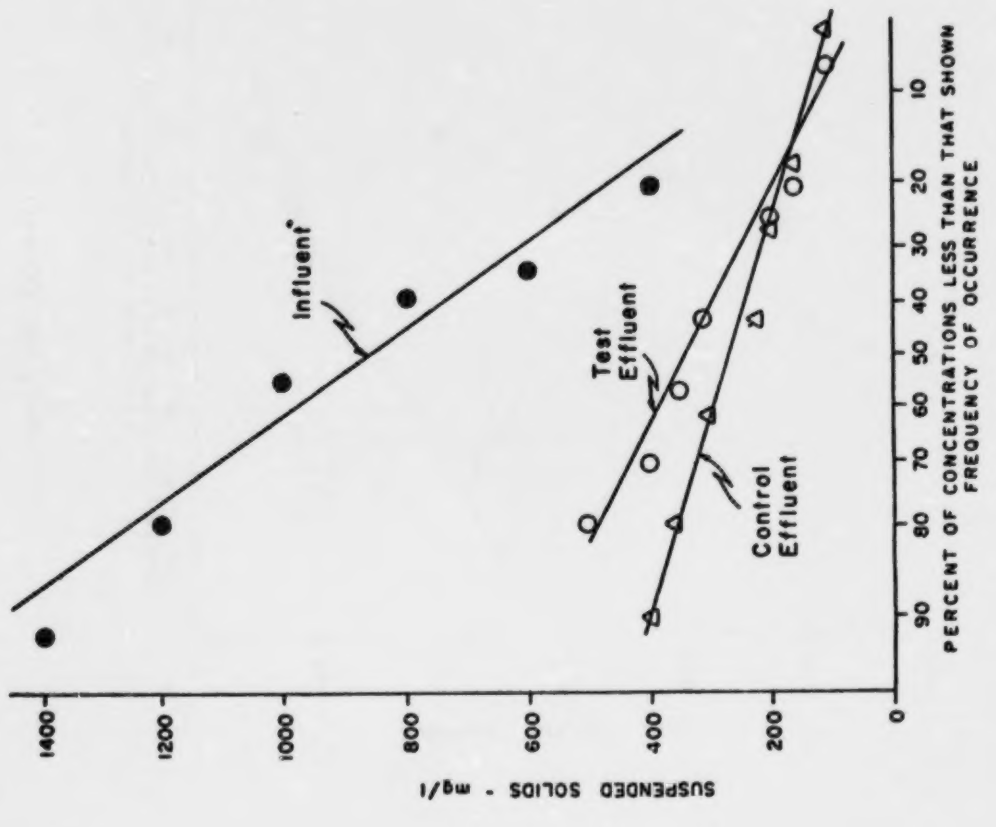
	Suspended Solids mg/l						BOD mg/l					
$FeCl_3$ Dosage	Inf.	Test	% Red.	Control	% Red.	Test Less Control	Inf.	Test	% Red.	Control	% Red.	Test Less Control
50 mg/l	863	348	59.6	262	69.6	-86	1589	905	43.0	916	42.3	11
100 mg/l	923	312	66.6	223	75.9	-89	2140	861	59.6	921	57.0	60

	No. Of Samples	t	p	No. Of Samples	t	p
50 mg/l	36	2.20	.03	14	0.27	.79
100 mg/l	36	1.66	.10	5	0.80	.47

Composite Samples

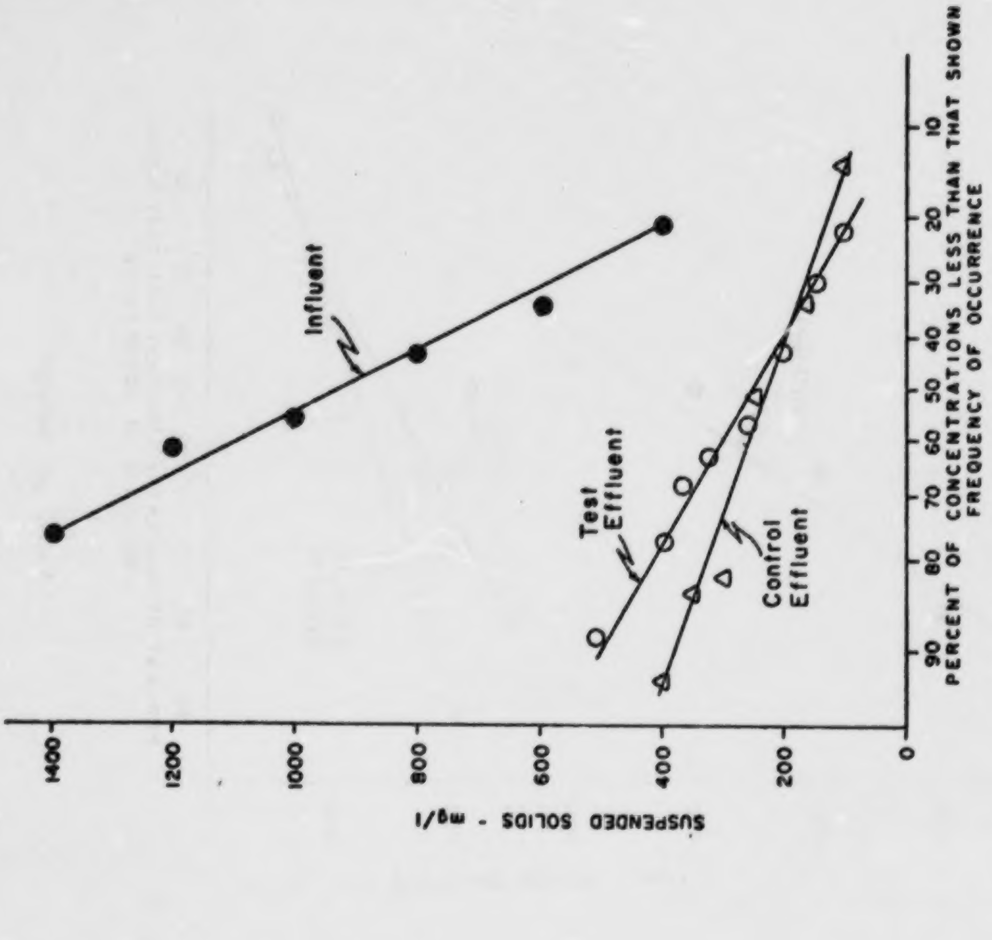
	Suspended Solids mg/l						BOD mg/l					
$FeCl_3$ Dosage	Inf.	Test	% Red.	Control	% Red.	Test Less Control	Inf.	Test	% Red.	Control	% Red.	Test Less Control
50 mg/l	891	351	60.5	242	72.8	-109	1389	725	47.7	744	46.4	19
100 mg/l	1014	484	52.4	236	76.7	-248	2075	630	69.5	805	61.0	175

	No. Of Samples	No. Of Samples
50 mg/l	5	5
100 mg/l	4	4



* - $FeCl_3$ at 50mg/l

FIGURE - II



- FeCl$_3$ at 100 mg/l

FIGURE - 12

PLANT EVALUATION ON SEPARATED PACKINGHOUSE AND DOMESTIC WASTES

Following the tests on ferric chloride some tests were run using the dual system on separated packinghouse and domestic waste. Packinghouse waste alone was tested for a number of days followed by tests on domestic waste only. The domestic waste was not truly domestic waste but included waste from the stockyards and waste from two small packing plants. While it was stronger than normal domestic waste, it more closely resembled a domestic waste than did the combined waste.

For both wastes preliminary jar tests were made to determine which of the polyelectrolytes previously used would be most effective on the separated waste. The results of these jar tests are shown in Tables 49 and 50. For the industrial waste 50 mg/l of ferric chloride was added followed by 1.0 mg/l of the polyelectrolyte. Dow A-23 was added to one beaker and Nalco 675 was added to a different beaker. In addition, a control sample of waste to which nothing had been added was stirred and sampled in the same manner. The dynamic method of sedimentation was used with samples for suspended solids being drawn off just below the surface while the flocculated wastewater was being stirred at 10 rpm. A sample of the degritted waste being tested was also taken. The results of these jar tests indicated no significant difference in effectiveness between Dow A-23 and Nalco 675.

It was decided it would be worthwhile testing either one of the polyelectrolytes on a plant scale. However, there was not enough time to give both a satisfactory test. Since a quantity of Dow A-23 sufficient for the test on industrial waste had been purchased earlier, it was decided to use this polyelectrolyte in testing the industrial waste.

The preliminary jar tests on domestic waste indicated that when using the dual system of ferric chloride and A-23 the dosage of ferric chloride

Table 49

Jar Tests On Industrial Wastes

$FeCl_3$ 50 mg/l Polyelectrolyte 1.0 mg/l
Suspended Solids mg/l

Test	Degritted Waste	Control	A-23	675
1	596	388	80	80
2	772	572	204	300
3	1012	620	256	220
4	1128	496	144	124
5	1248	680	140	124
6	1000	592	152	144
Ave.	959	558	163	165

A-23 vs. 675 t= .142 p= .89

Table 50

Jar Tests On Domestic Waste
Polyelectrolyte 1.0 mg/l

Test	Degritted Waste	Control	Dow A-23 With 20 mg/l $FeCl_3$	Nalco 675 With 20 mg/l $FeCl_3$	Nalco 675 With 50 mg/l $FeCl_3$
1	476	396	84	112	88
2	700	436	112	100	80
3	600	516	76	144	120
4	576	464	80	148	-
5	524	452	80	176	72
Ave.	555	453	86	136	90

A-23 + 20 mg/l $FeCl_3$ vs. Nalco 675 + 20 mg/l $FeCl_3$ t= 2.98 p .04

A-23 + 20 mg/l $FeCl_3$ vs. Nalco 675 + 50 mg/l $FeCl_3$ t= 0.036 $p > 0.90$

could be reduced to 20 mg/l and still produce a good floc. To obtain a floc of the same consistency with Nalco 675 it was necessary to use a dosage of 50 mg/l of ferric chloride. These results were verified by suspended solids tests as indicated in Table 50. The dosage of polyelectrolytes in both cases was 1.0 mg/l.

Eleven days of plant scale tests on the industrial waste were run first. This was enough to produce sufficient data for reliable statistical evaluation of the effectiveness of this dual system on the industrial waste. The chemical dosage used was 50 mg/l of ferric chloride and 1.0 mg/l of Dow A-23 from 8 AM to 10 PM with 30 mg/l of anhydrous ferric chloride and 0.75 mg/l of polyelectrolyte being added from 10 PM to 8 AM. Sampling and laboratory testing was done as in previous tests. A summary of the results of these tests are indicated in Table 50. The average suspended solids for the grab samples in the effluent of the control tanks was 162 mg/l and for the test tank it was 128 mg/l. The BOD showed a reduction from 951 mg/l in the control tank to 826 mg/l in the test. For suspended solids the reduction was somewhat less than observed for treatment of the combined waste. The conclusion drawn from this test was that treatment of separated industrial waste was not more effective than treatment of the combined waste. There would be no advantage to treating industrial waste only since a greater reduction in terms of total pounds of BOD and suspended solids could be obtained by treating the much larger flow of combined waste.

Following the test on industrial wastewater a test was run on domestic wastewater only. Initially a four day test was run using the higher dosage of ferric chloride with A-23. The dosages used were 50 mg/l of ferric chloride and 1.0 mg/l of Dow A-23 from 8 AM to 10 PM and 30 mg/l of ferric chloride and 0.75 mg/l of Dow A-23 from 10 PM to 8 AM. These dosages produced a dense, heavy floc. The dosage was then reduced to 20 mg/l of ferric chloride and 1.0 mg/l of Dow A-23. This dosage was fed 24 hours a day for a 7 day period. The summary of the results of these tests are shown in Table 51.

Table 51

Plant Scale Tests
Data For Wastewater Separation Tests
Summary Of Test Data

Chemical Dosage A-23 1.0 mg/l And Anhydrous $FeCl_3$*

		Suspended Solids mg/l				BOD mg/l			
Test	$FeCl_3$ Dosage	Inf.	Test	Control	Test Less Control	Inf.	Test	Control	Diff.
Average Grab Sample									
Combined	37.0	621	113	174	-61	1322	549	663	114
Industrial	49.7	824	128	162	-34	1571	826	951	125
Domestic	49.7	591	78	139	-61	1052	585	690	105
Domestic	20.5	523	98	130	-32	1019	418	528	110
Average Composite Sample									
Combined	37.0	631	106	171	-65	985	451	536	85
Industrial	49.3	896	140	172	-32	1412	761	848	87
Domestic	49.7	572	88	142	-54	594	440	445	5
Domestic	20.5	605	92	138	-46	790	385	445	60

*Actual average daytime dosage indicated in mg/l

During the first four days with the chemical dosage at the higher rate the average difference in suspended solids for grab samples in the effluent of the two tanks was about the same as it had been for the tests on the combined wastewater.

This was true in spite of the fact that the floc which was produced at the higher dosage appeared heavier and denser than that obtained with the combined waste. The average suspended solids in the grab samples of the effluent of the system was 130 mg/l for the control tank and 78 mg/l for the test tank. The BOD in the effluent of the control tank was 690 mg/l and in the effluent of the test tank 585 mg/l.

During the last seven days of the test on domestic wastewater the chemicals were added at a lower dosage rate. The floc that formed appeared to be about the same as that which had been formed during treatment of combined waste. The average reduction of suspended solids in grab samples did not bear this out, however. The suspended solids in the effluent of the control tank were 130 mg/l while 98 mg/l in the test tank, an improvement of only 32 mg/l. The improvement in BOD reduction in this test was about the same as for the first four days when chemicals were added at the higher dosage.

The conclusions drawn from this data are that the same dosage of 50 mg/l of ferric chloride and 1.0 mg/l of A-23 during the day and a dosage of 30 mg/l of ferric chloride and 0.75 mg/l at night were optimum for all three systems. Since no great improvement in effectiveness of the system nor any substantial reduction in chemical dosage could be realized by treating one or the other of the separated sewages, the most effective way to obtain the greatest overall reduction of suspended solids was to treat the combined flow.

When A-23 was used with 20 mg/l of ferric chloride it was significantly less effective than 675 with 50 mg/l of ferric chloride. When A-23 was used with 50 mg/l of ferric chloride the difference in effectiveness compared with 675 and 50 mg/l of ferric chloride was not significant. This seemed to negate the conclusion that Dow A-23 was more effective on domestic waste than was Nalco 675.

PLANT EVALUATIONS USING NALCO 675 AFTER DECEMBER 1, 1969

Further tests were run on Nalco 675 using combined, domestic and industrial waste to see how these compared with tests run using Dow A-23. It was necessary to run a new series of tests with Nalco 675 because Swift's packing plant had discontinued slaughtering operations since Nalco 675 was last tested.

An overall comparison of all data was made to determine if one or the other of the polyelectrolytes was more effective.

A test was made using full plant flow. Chemicals were added to the full plant flow in all three primary sedimentation tanks and samples taken throughout the plant for laboratory analysis. The chemical dosage was that found to be most effective considering all previous tests.

Laboratory parameters analyzed were: suspended solids, BOD, total phosphate and total kjeldahl nitrogen with the primary parameter being suspended solids. This test was run for a full month in order to determine what effect the chemical treatment would have on the biological treatment processes at the plant. Preceding this test was an equal period of time during which chemicals were not added to the plant but during which the same laboratory analyses were performed as a control.

A five day series of tests was started on combined waste using a dual system of ferric chloride and Nalco 675. The chemical dosages were ferric chloride at 50 mg/l and Nalco 675 at 1.0 mg/l from 8 AM to 10 PM and ferric chloride at 30 mg/l and Nalco 675 at 0.75 mg/l from 10 PM to 8 AM. The results are shown in Table 52.

The average of suspended solids for the tank effluent was 164 mg/l and the test tank effluent was 98 mg/l. The BOD of the effluent was 589 mg/l for the control tank and 465 mg/l for the test tank. Those results were equivalent to results obtained when tests were run using Dow A-23 and ferric chloride at equivalent dosages.

Following the tests on combined waste, tests were intiated on separated industrial waste from Armour's packing plant. The results are also shown in Table 52. The average suspended solids for grab samples taken at the effluent of the control tank was 204 mg/l compared to 130 mg/l in the effluent of the test tank. Tests for BOD in the effluent of these two tanks showed a reduction from 797 mg/l in the control tank to 585 mg/l in the test tank.

The third test run using the dual system of ferric chlrodie and Nalco 675 was run on the domestic wastewater received at the plant. As mentioned previously this was not entirely domestic wastewater but also consisted of waste from the stockyards and two smaller packing plants. The chemical dosages were the same as had been used in the two previous tests. A grab sample showed a suspended solids average for the control tank effluent of 149 mg/l while the test tank effluent was 74 mg/l. The BOD reduction for this test went from 414 mg/l for the control tank to 298 mg/l for the test tank.

A summary of results of tests run on combined and separated industrial and domestic systems are shown in Tables 50 and 52. The results indicate that Dow A-23 and Nalco 675 are both effective in reducing suspended solids and BOD. Statistical analysis of the data presented in Table 46 indicates the observed difference is not significant and based on the data available it must be concluded that two polyelectrolytes are equivalent.

Table 52 A

Plant Scale Tests
Data For Wastewater Separation Tests
Grab Samples

Summary Of Data
Comparing Dow A-23 With Nalcolyte 675
Chemical Dosage Dow A-23 1.0 mg/l And Anhydrous $FeCl_3$*

Waste	$FeCl_3$ Dose mg/l	Suspended Solids mg/l			Diff. Test -Cont.	Standard Deviation Of Ave. Diff.	Data Pairs	BOD mg/l			
		Inf.	Test	Cont.				Inf.	Test	Cont.	Diff.
Comb.	37.0	621	113	174	-61	±31.4	34	1322	549	663	114
Ind.	49.3	824	123	162	-34	±50.5	79	1571	826	951	125
Dom.	49.7	591	78	139	-61	±55.9	33	1052	585	690	109
A-23 And $FeCl_3$ at 20 mg/l	vs.	675 And $FeCl_3$ at 50 mg/l			t=3.46 p <.01	A-23 And $FeCl_3$ at 50 mg/l		vs.	675 And $FeCl_3$ at 50 mg/l		t= 1.42 p= .19
Chemical Dosage Nalcolyte 675 1.0 mg/l And Anhydrous $FeCl_3$											
Comb.	50.1	494	98	164	-66	±50.0	42	1001	465	589	124
Ind.	49.4	723	130	204	-74	±47.5	43	1490	584	797	213
Dom.	48.2	351	74	149	-75	±45.5	41	693	298	414	116

Waste--Combined, Industrial and Domestic

*Actual daytime dosages indicated in mg/l

Continued on next page

Table 52 B

Data For Wastewater Separation Tests (Continued)
Composite Samples
Summary Of Data

Dow A-23

Waste	Suspended Solids mg/l			Diff. Test -Control	Standard Deviation In Ave.	BOD mg/l			
	Inf.	Test	Control			Inf.	Test	Control	Diff.
Combined	631	106	168	-68	±20.1	985	451	536	-85
Industrial	896	140	172	-32	±16.2	1412	761	848	-87
Domestic	572	88	142	-54	±31.9	694	440	445	- 5
				Nalcolyte 675					
Combined	488	103	175	-72	±18.7	843	446	524	-78
Industrial	842	130	208	-78	±29.4	1467	568	652	-84
Domestic	358	76	141	-65	± 4.25	465	248	320	-72

Continued On Next Page

Table 52 C

Data For Wastewater Separation Tests
Statistical Analysis
Grab Samples
Summary Of Data Suspended Solids

Dow A-23

Waste	$FeCl_3$ Dosage	t	P
Combined	37.0	-11.39	<.01
Industrial	49.3	- 6.30	<.01
Domestic	49.7	- 9.65	<.01
Nalcolyte 675			
Combined	50.0	- 9.27	<.01
Industrial	49.4	- 7.24	<.01
Domestic	48.2	-10.04	<.01

Of the six tests using Dow A-23 and Nalco 675 on industrial, domestic, and combined wastewater, the greatest removal of solids and BOD was obtained on the combined wastewater.

The industrial wastewater when treated with ferric chloride and Nalco 675 resulted in a greater difference in concentration of suspended solids in the test and control tanks. Because of the larger volume of the combined waste definitely greater total quantities of suspended solids and BOD would be removed from the combined waste by chemical treatment than from either the industrial or domestic wastewater. To maximize BOD removal to meet effluent requirements the best system in a full plant-scale test would be the dual system of ferric chloride and Nalco 675 on the total combined wastewater coming into the plant.

SECTION X

RESULTS

All previous tests had been run on the influent and effluent to the sedimentation tanks. While these results indicated a significant increase in the effectiveness of primary treatment they did not in any way indicate how the chemical treatment process would effect the overall efficiency of the plant. This efficiency could be increased if the load on the biological treatment processes was reduced resulting in decreased effluent concentration from these units. If the chemicals resulted in lower efficiency of the biological treatment processes, however, the overall results would be uncertain. This lower efficiency might be the result of toxicity to microorganisms from the high dosage of ferric chloride or might simply result when a lesser organic load was applied to the treatment processes.

Sampling and laboratory testing were started a month before the actual chemical treatment tests. Parameters tested for in the laboratory were: suspended solids, BOD, total phosphorus, and total Kjeldahl nitrogen. Samples were taken hourly of the raw industrial and raw domestic influent and every two hours for the effluents of the grit chambers, primary sedimentation tanks, and secondary sedimentation tanks. The plant effluent was sampled every four hours. It was not necessary to sample the plant effluent more often than this since the seven day detention in the anaerobic stabilization pond tends to level off the flow and concentration resulting in a relatively uniform effluent. A composite sample based on flow was made for each sampling point. Laboratory tests were then run on these composite samples. Suspended solids tests were run on the composite samples and also daily on five grab samples from each of the sampling points.

In addition to the previously mentioned parameters which were examined to determine the effectiveness of the treatment process a biological examination was made to determine if there was any detrimental effect on the biota of the filters and the anaerobic stabilization pond. A consultant was hired to make a biological assay of the species and relative numbers of individuals of species on the surface rocks of the filters and at several stations in the pond from near the bottom to near the surface.

The necessary equipment for addition of chemicals was prepared. Two more distribution pipes were prepared to feed polyeletrolytes to the two tanks to which chemicals had not been previously fed. A larger feed pump was installed for the polyelectrolyte to enable the pumping of three times the volume of solution thereby allowing the solutions to be maintained at the same concentrations. The strength of the ferric chloride solution was increased to three times the concentration previously used to allow the use of the same chemical feed pump on full plant flow.

During the total plant scale chemical feeding test the entire flow of wastewater was directed through the chemical mixing chambers. The parallel flume which had carried the control wastewater in previous tests was shut off. Also, the line which had diverted excess wastewater not being tested to a third sedimentation tank was closed. After the entire flow had been passed through the chemical mixing chambers it was split so as to feed the same amount of wastewater to each of the three sedimentation tanks.

During the month preceding the chemical addition data was collected for the control period of the tests. During this period the plant was operated at maximun treatment capacity as it was in the following one month test period. All units were kept in continuous operation and any preventive maintenance requiring the shutdown of a unit was postponed until the completion of the tests. In addition, as much secondary sedimentation tank effluent as possible was recirculated daily. A 4.5 million liter (1.2 million gallon) storage tank was filled during the peak flow and this was recirculated through the plant at night.

After the one month control period chemical feed was started. An attempt was made to hold the daytime dosage of ferric chloride at 50 mg/l and the dosage of polyelectrolyte at 1.0 mg/l. The chemical dosage at night time and weekends was held at approximately 30 mg/l of ferric chloride and 0.75 mg/l of polyeletrolyte. The actual average chemical dosages as fed are given in Table 53. The overall average chemical dosage for the test period was 51.3 mg/l daytime ferric chloride feed and 1.07 mg/l daytime polyelectrolyte feed. The average actual dosage for night time and weekends was 28.6 mg/l ferric chloride and 0.70 mg/l polyelectrolyte.

The biota of the trickling filters and the pond was sampled biweekly during both control period and after chemical addition commenced. The addition of chemicals did not have a detrimental effect on the biota of either the trickling filters or the pond. While no significant change was observed in species of microorganisms, the species present appeared to be in greater abundance after chemical treatment. Appendix A is the report of the effect of chemical treatment on the biological treatment processes.

A summary of the data collected during the control and test periods are given in Tables 54 through 59. The suspended solids reduction for grab samples in the primary sedimentation tank was 63.0% for the control period and 78.5% for the test period. The average suspended solids removed in the primary tank during the control period was 320 mg/l compared to 369 mg/l during the last period. This is an average of approximately 100 sets of data obtained from the grab samples taken.

Table 53

Average Daily Chemical Dosage
mg/l

July 1970	Ferric Chloride		Nalco 675	
	8 am - 10 pm	10 pm - 8 am*	8 am - 10 pm	10 pm - 8 am*
1	47	28	1.00	0.67
2	66	34	0.76	0.72
3	71	22	1.30	0.62
4	--	29	--	0.83
5	--	28	--	0.74
6	55	30	1.00	0.72
7	45	28	1.10	0.58
8	50	31	1.08	0.55
9	48	34	0.85	0.79
10	47	32	0.82	0.86
11	--	26	--	0.68
12	--	27	--	0.75
13	45	24	1.20	0.63
14	54	29	1.39	0.62
15	53	21	1.05	0.55
16	47	22	1.11	0.70
17	62	29	0.90	0.69
18	--	25	--	0.70
19	--	33	--	0.69
20	51	28	1.11	0.76
21	53	36	1.07	0.93
22	43	33	0.83	0.76
23	62	25	1.00	0.80
24	44	26	0.92	0.71
25	--	29	--	0.64
26	--	20	--	0.58
27	41	28	0.89	0.71
28	43	29	0.98	0.72
Average	51.3	28.6	1.07	0.70

* 24 hour dosage on Saturdays & Sundays

This data follow the same trend as data collected on partial flow tests run on the primary sedimentation tank as descirbed previously. This reduction in suspended solids did not carry throughout the plant, however. A smaller loading on the filters and the anaerobic pond resulted in less reduction in these units. For suspended solid run on grab samples, the filters showed a reduction of 118 mg/l for the control period and only 59 mg/l for the test period. The pond showed a suspended solids reduction on grab samples of 20 mg/l for the control period and 9 mg/l for the test period.

The suspended solids run on the composite samples for which there were approximately 20 sets of data for both the test and control period showed about the same results. A summary of these results are given in Table 55. During the control period 202 mg/l of suspended solids were removed in the primary settling tanks while 255 mg/l were removed during the test period. The filters again showed a greater reduction in suspended solids during the control period when loadings were greater. A reduction of 89 mg/l was obtained as the wastewater passed over the filters and through the secondary settling tank during the control period while only 49 mg/l of suspended solids were removed by this secondary treatment process during the test period. The lower suspended solids and BOD removal on the filters was a result of the reduced load applied to the filters. The efficiency of the filters was not significantly changed as indicated by the results of the "Student" t-test run on efficiencies and presented in Table 55. The composite sample showed a suspended solids reduction of 48.4% during the test period and 57.0% during the control period and a BOD reduction of 64.5% during the test period and 70.0% during the control period. This difference in efficiencies is not statistically significant. The BOD reduction obtained in the primary tank was 53.8% in the test period and 29.2% in the control period. This was significant at the .05 level as indicated in Table 55. The reduction obtained in the primary tanks did not result in a change in efficiency on the filters and the reduction in the primary tank resulted in a significant difference in the effluent of the secondary treatment process for the test and control periods.

The suspended solids reduction in the pond for composite samples was about the same for the control and test periods, being 18 mg/l and 20 mg/l, respectively. For both, the composite sample and the grab sample the pond effluent did have slightly higher concentrations of suspended solids during the control period than during the test period.

This is probably because the control period was started before the spring turnover in the pond was complete and a larger amount of settleable solids were in the effluent than during the test period. The settleable solids for the composite sample are given in Table 59. The average of settleable solids for the control period was 0.63 mg/l compared to 0.12 mg/l for the test period. These solids are relatively stable from digesting on the bottom of the pond having volatile suspended solids of about 64%. They, therefore, do not show up as an increased BOD. Due to these settleable solids the observed difference in suspended solids in the pond effluent for the test and control period was probably not the result of chemical addition.

The results of the BOD test on composite samples are shown in Table 55. A significantly greater amount of BOD was removed in the primary sedimentation tanks during the test period than during the control period. A reduction of 148 mg/l of BOD was obtained during the control period, compared to a BOD reduction of 314 mg/l during the test period. Again, the reduced loadings on the filters and pond caused a lower removal in these two units for this parameter. The efficiency of the filters remained unchanged, however. The BOD reduction on the filters for the control period was

250 mg/l while a reduction of 203 mg/l was obtained during the test period. The BOD of the secondary settling tank effluent was substantially lower during the test than during the control period being 66 mg/l and 107 mg/l, respectively. These results are shown in Figure 13.

The phosphorus removal by the chemical treatment process was significant as indicated in data for the composite sample in Table 55. Over twice as much phosphorus was removed in the primary sedimentation tank during the test period as during the control period. The phosphorus reduction during the test period was 5.3 mg/l compared to 2.5 mg/l during the control period. The amount of phosphorus removed on the filters was about the same for the test period and control period. In the pond a slight increase in phosphorus was observed for both the test and control period. This was due to the fact that the sludge supernatant from the sludge lagoons flows into the pond returning some of the phosphorus previously removed. The amount of phosphorus returned to the pond during the test period was only slightly greater than that returned during the control period. This overall phosphorus reduction for the plant was 51.9% for the test period, or about twice that for the control period which was 26.0%.

The results of total Kjeldahl nitrogen tests run during the test and control period are given in Table 55. A small but significant difference was observed in the reduction of total Kjeldahl nitrogen as a result of the chemical treatment process. Again, an increase in nitrogen was observed in the pond for both the test and control period because of carry over in the sludge supernatant.

The flow data and data on chlorine requirements for the control and test periods are given in Tables 54 and 56, respectively. The average wastewater flow is slightly less than the influent flow as a result of leaching at the bottom of the pond and evaporation from the 11 hectare (27 acre) surface area.

BOD AT SAMPLING POINTS
CONTROL PERIOD AND TEST PERIOD
FULL PLANT SCALE CHEMICAL TESTS

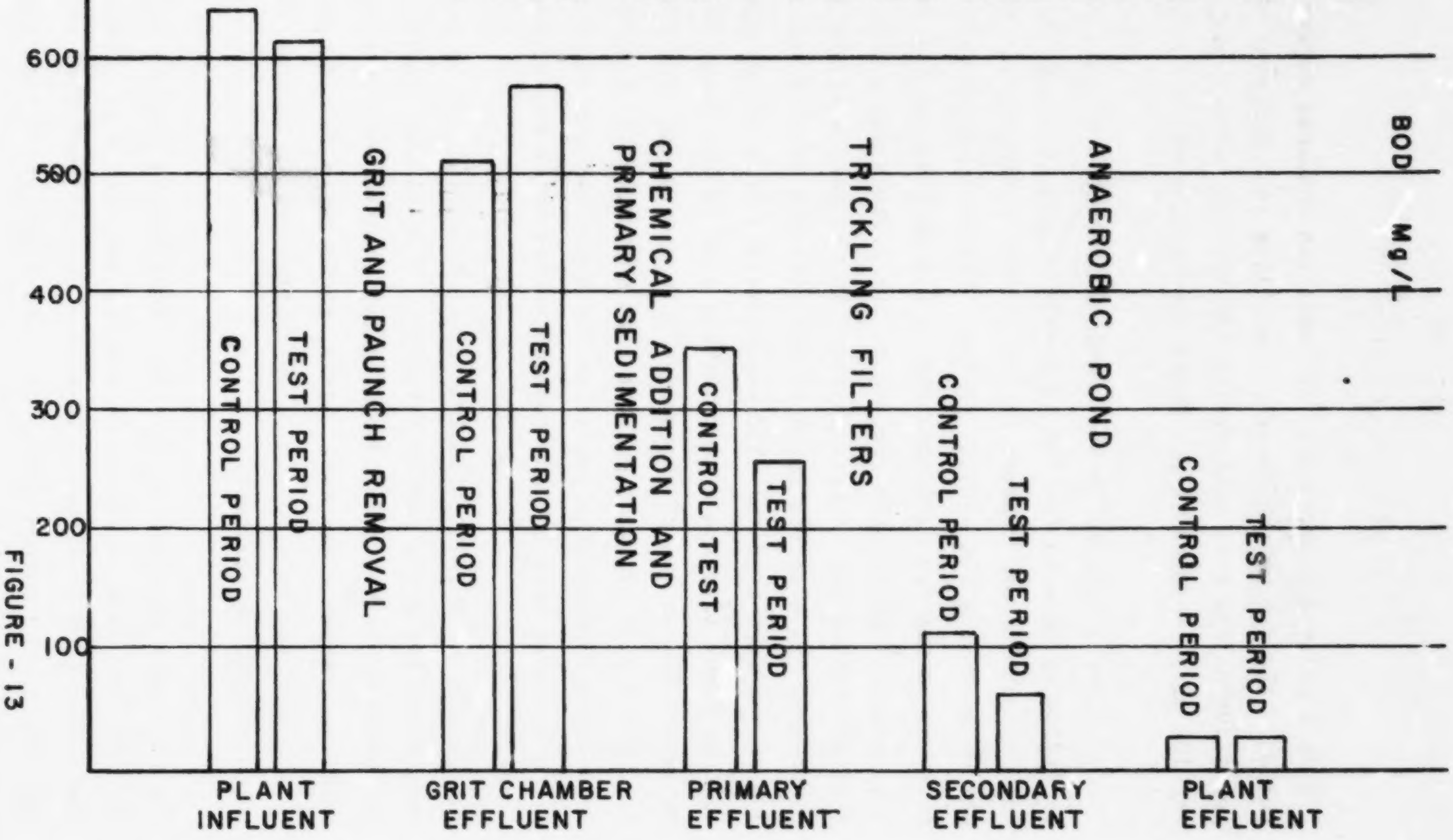


FIGURE - 13

Table 54

Flow And Chlorine Data
Control Period

Date 1970	Flow MGD		Chlorine Data	
	Influent	Effluent	Chlorine Demand mg/l	Pounds Used*
May 20	--	8.05	16.8	1130
May 21	--	9.12	18.6	1416
May 22	10.10	12.76	17.6	1820
May 25	10.22	8.69	15.9	1132
May 26	9.47	9.37	10.0	780
May 27	10.78	11.22	10.0	932
May 28	8.61	12.63	12.2	1280
June 1	9.28	9.08	17.0	1290
June 2	8.82	8.88	17.5	1240
June 3	8.51	8.41	18.5	1296
June 4	8.00	7.49	14.1	878
June 5	9.15	8.20	16.7	1144
June 8	9.08	8.48	14.5	1028
June 9	9.25	9.40	15.5	1216
June 10	9.66	9.93	15.1	1222
June 11	8.60	8.08	13.1	1060
June 12	11.88	9.79	15.4	1252
June 15	12.13	9.46	18.2	1308
June 19	10.76	8.70	13.6	984
June 22	10.00	7.93	13.4	884
June 23	--	9.10	12.9	980
June 24	--	9.46	10.9	860
June 25	--	9.75	10.5	840
June 29	11.22	9.03	10.1	762
MEAN	10.31	9.29	13.9	1113
# Of Samples			24	24

* Based on actual measurement

Table 55 A

Data Of Full Plant Scale Chemical Treatment

Composite Sample

	Test Period			Control Period		
Sample Point	Sus. Solids mg/l	Reduction	Percent Reduction	Sus. Solids mg/l	Reduction	Percent Reduction
Raw	552			621		
Grit Eff.	356	196	35.5	359	262	42.2
Prim. Eff.	101	255	71.7	157	202	55.6
Secondary Eff.	52	49	48.4	68	99	57.0
Pond Eff.	32	20	38.5	50	18	26.5
Percent removal by the entire plant			94.2			92.0
Number of samples	20				24	

	Test Period			Control Period		
Sample Point	BOD mg/l	Reduction	Percent Reduction	BOD mg/l	Reduction	Percent Reduction
Raw	616			634		
Grit Eff.	583	33	5.3	505	39	4.6
Prim. Eff.	269	314	53.8	357	148	29.2
Secondary Eff.	66	203	64.5	107	250	70.0
Pond Eff.	22	44	66.6	28	79	73.8
Percent removal by the entire plant			96.4			94.5
Number of samples	20				22	

Table 55 B

Statistical Evaluation Of Change In Unit Efficiency With Chemical Treatment

Unit And Parameter	No. Of Trials		Std. Deviation			
	Test	Control	Test	Control	t	p
Primary Sedimentation Tanks						
Sus. Solids	20	23	8.2	16.9		
BOD	19	20	10.0	11.0	5.61	.01
Trickling Filters						
Sus. Solids	20	24	23.2	25.2	1.06	0.29
BOD	19	21	10.3	11.3	.971	0.33

Table 55 C

Sample Point	Test Period Phosphorus mg/l	Test Period Reduction	Test Period Percent Removal	Control Period Phosphorus mg/l	Control Period Reduction	Control Period Percent Removal
Raw	12.9			12.7		
Grit Eff.	10.9	2.0	15.5	11.5	1.2	9.4
Prim. Eff.	5.6	5.3	48.4	9.0	2.5	21.8
Secondary Eff.	4.7	0.9	16.1	8.5	0.5	5.6
Pond Eff.	6.2	-1.5	--	9.4	-0.9	--
Percent Removal by the entire plant			51.9			26.0
Number of Samples		20		22		

Sample Point	Test Period Nitrogen mg/l	Test Period Reduction	Test Period Percent Removal	Control Period Nitrogen mg/l	Control Period Reduction	Control Period Percent Removal
Raw	55.9			56.0		
Grit Eff.	55.7	0.2	0.35	49.1	6.9	12.3
Prim. Eff.	42.9	12.8	23.0	43.5	5.6	11.4
Secondary Eff.	30.5	12.4	28.9	34.2	9.3	21.4
Pond Eff.	38.9	-8.4	--	46.6	-10.5	--
Percent Removal by the entire plant			30.5			20.1
Number Of Samples		20		24		

Table 55 D

Statistical Analysis Of Full Plant
Scale Chemical Treatment Data

Composite Samples - Primary Effluent

Parameter	No. Of Trials		Mean		Std. Deviation		t	P
	Test	Control	Test	Control	Test	Control		
Suspended Solids mg/l	20	24	101	157	39	55	3.81	<.01
BOD mg/l	19	22	269	357	65	73	4.04	<.01
Phosphorus mg/l	20	24	42.9	43.5	10.8	3.4		
Nitrogen mg/l	20	22	5.6	9.0	1.54	1.02		

Table 55 E

Statistical Analysis Of Full Plant
Scale Chemical Treatment Data

Composite Samples - Trickling Filter Effluent

Parameter	No. Of Trials		Mean		Std. Deviation		t	P
	Test	Control	Test	Control	Test	Control		
Suspended Solids	20	24	52	68	±19.2	±25.8	2.17	.03*
BOD mg/l	20	22	66	107	±25.6	±55.8		
Phosphorus mg/l	20	22	4.7	8.5	± 1.07	± .85	41.6	<.01*
Nitrogen mg/l	20	24	30.5	34.2	± 5.28	± 5.61	2.24	.03*

* Indicates significant difference in Mean at the 0.05 level

Table 55 F

Statistical Analysis Of Full Plant Scale Chemical Treatment Data

Composite Samples - Plant Effluent

Parameter	No. Of Trials		Mean		Std. Deviation		t	p
	Test	Control	Test	Control	Test	Control		
Suspended Solids mg/l	20	23	32	50	±10.3	±24.1		
BOD mg/l	20	22	22	28	± 6.78	± 7.50	.446	.66
Phosphorus mg/l	20	22	6.2	9.4	± 1.16	± 0.56		
Nitrogen mg/l	20	24	38.9	46.6	± 4.41	± 5.43	5.10	<.01*

*Indicates a significant difference in the Means at the 0.05 level

Table 56

Flow And Chlorine Data
Test Period

Date	Flow MGD		Chlorine Data	
1970	Influent	Effluent	Chlorine Demand mg/l	Pounds Used*
June 26	--	9.47	14.1	1040
July 1	10.91	10.80	9.6	944
July 2	--	10.05	14.5	1216
July 6	10.97	8.34	6.2	432
July 7	11.81	10.97	4.6	424
July 8	11.35	11.00	4.1	372
July 9	14.27	12.26	2.8	284
July 10	8.73	12.10	5.2	520
July 13	9.98	6.57	3.0	164
July 14	7.57	8.57	8.4	600
July 15	8.18	6.91	3.4	196
July 16	8.31	7.45	3.9	244
July 17	7.73	7.41	3.8	232
July 20	6.62	3.82	6.6	212
July 21	9.60	7.55	2.7	172
July 22	10.61	9.63	3.5	284
July 23	10.59	9.55	4.0	316
July 24	--	10.00	3.6	300
July 27	--	9.04	3.1	236
July 28	--	10.79	2.8	248
Mean	9.81	9.11	5.5	422
# Of Trials	15	20	20	20

* Based on actual measurement

Table 57

Grab Samples
Data Of Full Plant Scale Chemical Treatment

Suspended Solids Grab Samples
Control Days Average

Time	Raw Ind.	Raw Dom.	Grit Eff.	Prim. Eff.	Final Eff.	Time	Pond
10 a.m.	1095	675	543	140	48	8 a.m.	43
12 Noon	1091	780	526	204	63	12 Noon	52
2 p.m.	1041	773	506	214	79	4 p.m.	62
4 p.m.	846	874	699	221	86	8 p.m.	50
8 p.m.	432	500	269	161	69	12 Mid.	44
Ave. Of All Data	902	720	508	188	70	--	50

Suspended Solids Grab Samples
Test Days Average

Time	Raw Ind.	Raw Dom.	Grit Eff.	Prim. Eff.	Final Eff.	Time	Pond
10 a.m.	1032	737	529	71	34	8 a.m.	33
12 Noon	1145	703	525	109	42	12 Noon	34
2 p.m.	1235	602	427	115	49	4 p.m.	33
8 p.m.	325	350	246	88	42	12 Mid.	34
Ave. Of All Data	923	591	470	101	42	--	33

Table 58

Flow And Chlorine Data Summary

	Test Period	Control Period
Influent Flow	9.81	10.31
Effluent Flow	9.11	9.29
Chlorine Demand	5.5	13.9
Pounds of Chlorine Used	422	1113
Chlorine Cost At 7.5¢/lb.	$31.65	$83.47
Chlorine Cost/mg	$ 3.23	$ 8.10

Table 59

Settleable Solids Pond Effluent
24 Hour Composite ml/l

Control Period	
May 20	0.5
May 21	1.5
May 24	0.3
May 25	0.4
May 26	1.4
May 27	0.6
May 28	2.6
June 1	0.5
June 2	0.5
June 3	0.2
June 4	0.3
June 5	0.5
June 8	0.9
June 10	0.4
June 11	0.6
June 12	0.4
June 15	0.4
June 16	0.7
June 19	2.6
June 22	0.2
June 23	0.4
June 24	0.2
June 25	0.5
Average	0.63

Test Period	
June 26	0.2
June 28	0.1
June 29	0.2
July 1	0.1
July 2	0.1
July 8	0.2
July 9	0.2
July 10	0.1
July 12	0.0
July 14	0.2
July 15	0.1
July 16	0.1
July 19	0.1
July 20	0.1
July 21	0.1
July 22	0.1
July 23	0.1
July 24	0.0
July 26	0.1
July 27	0.2
Average	0.12

About a week after chemical treatment a sharp drop was observed in chlorine demand. This is one unanticipated beneficial result from using the chemical treatment process. The average chlorine demand for the control period was 13.9 mg/l while for the test period it was 5.5 mg/l. This is a substantial reduction in total use of chlorine and would help to offset the cost of chemicals in a plant scale operation. The reduction in cost of chlorination was $1.29 per million liters ($4.87 per million gallons). This is shown in Table 58.

The chlorine demand rose slowly after the use of chemicals was discontinued taking approximately a month to reach the level it had been before chemical treatment was started. Again, this may not be entirely attributable to the ferric chlirde since during the later part of the test period, due to algae, there was dissolved oxygen in the effluent. The presence of free dissolved oxygen no doubt also oxidizes the hydrogen sulfide thus reducing the chemical chorine demand. It was only when the effluent turned green that the D.O. tests were run. The effluent turned green the last week of the test period and most of the D.O. tests were run after the test period. Only two D.O. tests were run before this, one during the control period and one during the test period. Both of these tests showed a zero D.O. Of course, this presence of algae could have been stimulated by the forming of an insoluble precipitate of ferrous sulfide which reduced the immediate oxygen demand allowing the algae to multiply and thus generate more oxygen by the photosynthetic process. This latter condition seems to be what happened since the chlorine demand started increasing slowly after discontinuing the test and by September 22 was nearly equal to the chlorine demand prior to the chemical feeding. Also, the green color due to algae slowly disappeared.

The overall results of the data collected during this test indicate that no significant increase in BOD or suspended solids removal could be achieved at the South St. Paul plant by the use of this chemical treatment process. If it were not for the anaerobic pond as the final treatment process, chemical treatment might be worth considering as an interim method of treatment since the BOD in the effluent of the secondary sedimentation tank for the test period was significatly lower than that for the control period. The BOD of the filter effluent was 66 mg/l during the test period and 107 mg/l during the control period. This is a significant difference in BOD and was the result of chemical treatment.

In deciding whether or not to use chemical treatment in a trickling filter plant it would be necessary to consider if this reduction was sufficient and whether it could justify the cost of chemicals. For a treatment plant treating packinghouse wastes with primary treatment only, this dual system of chemicals could be of value in reducing suspended solids and BOD.

Whether or not a system is practical depends upon the cost of operation. The plant-scale system tested at South St. Paul did not prove to be practical. However, if it were used at a chemical treatment plant not followed by biological treatment the economic consideration would be of importance.

The cost of operations of chemical treatment facilities are dependent upon plant size. The costs of operation were calculated on the basis of a 438 l/sec (10 mgd) flow. Labor, capital construction, and utility costs are based on information obtained during the plant-scale evaluation. Chemical costs are based on dosage utilized in the plant investigation and price quotes from the chemical companies. The plant evaluation utilizing full-scale equipment offers reliable cost information. A summary of these costs are shown in Table 60.

The cost of ferric chloride is $0.121 per kilogram ($0.055 per pound), for large quantities delivered to the nearby Metro plant. Both polyeletrolytes were priced at $3.52 per kilogram ($1.60 per pound) plus $0.044 per kilogram

Table 60

Economics
Based On A 10 MGD Flow

Item	$/Year	% Of Total
Chemical and handling cost	$117,416	71
Capital construction and maintenance (piping, chemical building and feeding equipment)	24,958	15
Labor (Operator, sampler, chemist)	19,100	12
Utilities (Gas, water electricity)	2,760	2
TOTAL	$164,234	100

($0.02 per pound) freight for 2270 kilogram (5000 pound) lots. The dosages used were 50 mg/l ferric chloride and 1.0 mg/l polyeletrolyte for 14 hours and 30 mg/l and 0.75 mg/l, respectively for 10 hours. Chemical handling costs were estimated at $3,500 per year.

The capital construction was amortized over 30 years for the chemical building, 5 years for the feeding equipment, and 20 years for the special piping, all at a 5% rate of interst. Maintenance of these items was estimated at $2,500 per year. Labor costs were figured at 3120 hours per year at $5.00 per hour. This manpower is necessary to operate the feeding equipment, chemical preparations, and sampling. Laboratory equipment and 0.3 man-years of a chemist's time cost an additional $3,500 per year. The costs of electricity, gas, and water were estimated on a monthly basis of $168, $20, and $42, respectively.

A reduction in cost of $1.29 per million liters ($4.87 per million gallons) was realized from reduced chlorine demand. This was subtracted from the cost of chemical treatment.

The total cost of chemical treatment over and above the normal operating costs of the plant came out at $10.58 per million liters ($40 per million gallons). Since it is considered likely that the reduction in chlorine demand occurred in the pond, the cost of chemical treatment for a trickling filter plant without an anaerobic pond as a final treatment step would be $11.90 per million liters ($45 per million gallons).

SECTION XI

PUBLICATIONS AND PATENTS

1. Larson, K. D., R. D. Crowe, D. A. Maulwurf, and J. L. Witherow. "The Use of Polyelectrolytes in the Treatment of Combined Meat-Packing and Domestic Wastes." (Presented at the Water Pollution Control Federation Annual Conference, 1970).

2. Patent pending: July 25, 1969. "Process for Improving the Treatment of a Combined Mixture of Domestic and Meat Packing Wastes."

   For: U. S. Department of the Interior, Environmental Protection Agency, Water Quality Office.

   Description: The use of a dual chemical system of ferric chloride followed by a high molecular weight organic anionic polyelectrolyte to effectively flocculate the waste, thereby improving the removal of suspended solids and biochemical oxygen demand (BOD) in the primary clarification step of a waste treatment plant.

SECTION XII

APPENDICES

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APPENDIX A

Report On The

Biological Changes in the South St. Paul Sewage Treatment Plant Before And After Treatment With $FeCl_3$ And Naclytle 675 Coagulating Agents

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Project Initiated: June 15, 1970
Project Terminated: July 28, 1970

Completion Report Submitted: September 10 , 1970

INTRODUCTION

The major objective of modern wastewater treatment is the removal of putrescible organic matter, therefore reducing the biochemical oxygen demand (BOD). At the South St. Paul Sewage Treatment Plant the initial mechanical solids removal of domestic and industrial wastewater is very efficient due to the fact that the primary tanks are preceded by pre-primary tanks and flocculation units. Even so, due to the nature of the predominately packing plant industrial sewage, a considerable load of organic matter and complex inorganic colloidal particles remain in suspension. Many of these particles are large enough to settle out and are removed by bottom-scrapers in pre-primary settling tanks. However, as is well known, additional settling of even colloidal sized particles can be effected by feeding chemical coagulating agents to wastewater. Therefore at the South St. Paul Sewage Treatment Plant (as will be expanded on in their general report) a demonstration project was planned to test the efficiency of using cations and polyelectrolytes.

METHODS AND MATERIALS

Ferric chloride ($FeCl_3$) at 50 mg/l and Nalcolyte 675 anionic polyeletrolyte at 1 mg/l final concentrations, were fed to the wastewater after pre-primary settling from June 26, 1970 to July 27, 1970, with a minor shut-down due to pump failure from June 27 to 29, 1970. The coagulant entered the wastewater in mechanically stirred flocculation tanks prior to entering the primary settling tank. Sampling was conducted before treatment (June 17 and 24) and during or after treatment commenced (July 8 and 22) with an inspection trip concerning a peculiar algal bloom July 29, 1970.

Trickling filter stones were collected from the surface and placed in sterile 18 oz. Whirl-Pak (NASCO) bags. Most organisms were identified and original illustrations were made of each (Plate I) to acquaint the reader with the biota. The association of organisms was carefully tabulated so that any severe changes or treatment effects could be singled out.

The anaerobic stabilization pond was sampled using a 12 foot boat where six stations were established about 450 feet apart, and number seven station at the pond effluent about 900 feet from station 6 (Fig. A1). At each station samples were collected with a modified PVC dissolved oxygen sampler (Hach, 1968). A 6 oz. sterile Whirl-Pak bag was placed into the sampler after sterilizing the sampler cover by soaking it in 95% isopropyl alcohol. The device was lowered to about 7 feet, opened and raised to the surface, therefore obtaining an integrated (composite) sample representative of the 7 foot column of water. The composite water sample thus obtained was collected in a sterile container making bacteriological analysis possible. Bacteria were diluted from 0.01 to 0.000001, to insure a plate count from 30 to 300 colonies, and each dilution was plated in triplicate in Triptone Glucose Extract Agar (or plate count agar) incubated for 48 hours at 35½F (Standard Methods, 1965). A thin layer of sterile TGEA was poured over the culture agar to retard the growth of fungi and strict aerobic bacteria since the pond was anaerobic (o mg/l dissolved oxygen from the Winkler test). Colonies were counted and recorded as colonies per milliliter of pond water. Plate II illustrates many anaerobic stabilization pond biota.

Algae were filtered in 1 to 5 ml aliquots on 0.45 micron Millipore-filters. Filters were placed on glass slides and cleared with immersion oil and stored with a cover glass over them. The algae on the filters were enumerated according to the procedure of McNabb (1960). All algae were identified from wet mounts in the living condition, an absolute prerequisite for the McNabb method. Protozoans were identified but not counted, although many are illustrated on Plate I and Plate II. Water temperature was recorded at each station with a thermistor and dissolved oxygen samples were taken periodically using the Azide modification of the Winkler tehcnique (Standard Methods, 1965). Secchi disc transparency was an additional physical measurement taken at each station on the anaerobic stabilization pond. This measurement consists of lowering into the water a 20 cm black and white painted disc to the depth which it can no longer be seen and recording this depth as the limit of transparency using the human eye as the sensitive photo cell. All sampes were kept in a styrofoam cooler during transportation to St. Cloud, Minnesota and were evaluated immediately, less than 6 hours after their collection.

RESULTS AND DISCUSSION

1. Biological Filter (or Trickling Filter) microorganism analysis-- A qualitative analysis of surface filter stones revealed a unique association of organisms. Most abundant was the slime colonial bacterium *Zoogloea ramigera* which covered the stones. At the fringe (contact with other stones) of each stone was the grey colored filamentous fungus *Geotrichum candidum* that forms a felt-like mat in and upon which supported the growth of the grazers, nematode worms and *Psychoda* the filter fly larvae. Surface stones, being exposed to solar radiation also support the growth of photosynthetic organisms (the algae), as opposed to *Zoogloea* and *Geotrichum* that obtain their nourishment heterotrophically or saprophytically from decaying organisms or the rich wastewater being continuously sprinkled on them.

The algae reponsible for the dull green to blue-green appearance of the surface stones are the domiant algae *Chlorococcum sp.* and *Nitzschia palea* along with *Phormidium sp.*, *Anacytis sp.*, *Ulothrix sp.* and *Uranema sp.* No significant change in this association of species, with respect to number of species and dominance, was noted after treatment with the coagulating substance. However, each appeared to be in greater abundance after treatment.

2. Anaerobic Stabilization Pond Bacteriological Analysis--Table A1 and Figure A2 show the before and after treatment effect on the pond and bacteria density. In all cases bacterial numbers decreased from station 1 to station 7 (pond effluent). This is to be expected since bacterial numbers are very high (especially coliform organisms) in raw sewage and diminish as the wastewater passes through the plant. The magnitude of decrease is not great in the pond and is not considered unusual. However, there was a distinct increase in bacteria numbers after the $FeCl_3$ and polyelectrolyte were added. The increase was by a factor range of 5X to 8X at station 1 and 7X to 18X at station 7. The sudden change in bacterial density after or during treatment is considered significant. Therefore, since there was an increase in density, hence an increase in matabolism it is considered a beneficial change; more saprobic biological activity increases the breakdown of non-refractory organic matter into simple inorganic compounds and readily decomposable bacteria cells.

3. Anaerobic Stabilization Pond Algal Analysis--Under anaerobic conditions (absence of oxygen) one would expect to find none to a small number of algal species. This was the case since only 6 species were dominant and considered of value and autochthonous (produced in the pond). They are: *Chlorella vulgaris*, C. *ellipsoidea*, *Palmellococcus protothecoides*, P. *miniatus*, *Nitzschia pales*, and *Pyrobotrys gracilis*. *Nitzschia* and *Chlorella* and common sewage algae and can temporarily live heterotrophically, and the others need considerable research. The importance of algae in this anaerobic stabilization pond that has a mean BOD range of 218 to 492 mg/l is probably not significant since the strong anaerobic habitat restricts algal growth and restricts the number of species that can tolerate anaerobiasis. This is in direct opposition

to aerobic stabilization or oxidation ponds that are aerobic during the day and become slightly anaerobic at night due to microorganism respiration, BOD. Oxidation ponds have a 3 to 4 week detention period and rely largely on algal photosynthesis to provide oxygen for aerobic bacterial metabolism. Table A2 and Figure A3 show the abundance of algal cells for each station for the four sampling periods. Algal numbers were always lowest at station 1 (clarified sewage influent to the pond) and generally increased to station 7 (pond effluent). Before treatment total algal populations ranged from 1,060/ml to 5,890/ml and averaged 2,720/ml, while one week after treatment started algae ranged 2,060/ml to 7,490/ml and averaged 4,650/ml. This is considered a minor fluctuation and represents a 1.7 fold increase after treatment. However, two weeks later during treatment algal density increased greatly ranging from 7,330/ml to 960,670/ml averaging 382,100/ml, or a factor of 140X from before treatment values. On July 28, 1970, Mr. Keith Larson notified me to check the algal bloom present in the stabilization pond. Upon examination of the samples which recorded 1,800,100 cells/ml the same 6 species were represented as listed earlier, mostly Chlorella however. The fact that Mr. Larson has never noted algal blooms in the stabilization pond since its construction in 1963 makes this bloom after treatment with $FeCl_3$ and polyeletrolyte coagulating agents highly significant. Since water temperature varied little (Table A3), Secchi disc transparency remained about one foot and solar radiation was not atypical, the possible direct or indirect effect of the coagulating agents on the bloom is plausible. However, the bloom also coincided favorably with lower BOD values in the pond since Swift ceased slaughtering operations and the lower pond BOD probably stimulated algal growth. During slaughtering operations (1963-Nov., 1969), the pond BOD average ranged 492 mg/l from the influent to 218 mg/l at the effluent. Since December, 1969, to August, 1970, the average range was

202 to 63 mg/1, repectively. Lowest values occurred during the bloom in July, 1970, 22 mg/1 BOD. This climbed after the bloom occurred to the August monthly average of 43 mg/1 BOD. The lowest pond BOD (22 mg/1) probably also resulted from and stimulated algal growth and hence oxygen production. During the bloom and to mid-August dissolved oxygen was noted during day-light hours at the pond effluent (peaked at 2.5 mg/1) to 5 August 1970). The samples taken by the sewage plant chemists showed typical oxidation pond mid-day highs and early morning-late day lows. No samples were taken at night, but they probably would show no dissolved oxygen. The slight increase in algae was noted in the July 8 samples, when bacteria also increased greatly from the two before treatment samples. Algae probably responded more slowly to the environmental changes than the bacteria.

The reduction of colloidal particles and suspended solids by coagulating agents should have reduced the turbidity in the pond, No reduction was recorded since the Secchi disc transparency measurements varied little (mostly 11-13 inches) throughout the sampling period (Table A3). The pond is continuously mixed internally by upwellings of soft organic matter brought on by trapped gas (CO_2, CH_4, H_2S) in the bottom sediments. Reduction in turbidity would cause increased algal bloom. It is probably related to the addition of coagulating agents. Again, increased growth of microorganisms, algae and bacteria, is beneficial and hastens the utilization and decomposition of non-refractory organic matter.

Table A4 provides a systematic list of the biota found on surface stones of the biolgical filters and from 0 to 7 feet of the anaerobic stabilization pond during June and July, 1970.

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GLOSSARY

AEROB (AEROBIC). Organisms that can prosper only when oxygen is present more or less abundantly (Gr. Aer=air, bios=life).

ALGAE (ALGA). Simple plants, many microscopic, containing chlorophyll. Most algae are aquatic and may produce a nuisance when environmental conditions are suitable for prolific growth.

ANAEROBE (ANAEROBIC). Organisms which either by obligation or facultatively thrive in the absence of oxygen (Gr. an=without).

ASSOCIATION. An association in biology includes the entire organism population of a given habitat with two or more organism species dominating the group.

AUTOCHTHONOUS. Arising in the biological system under consideration (Gr. autos=self, same, chthon=land).

AUTOTROPHIC. The nutrition of those plants that are able to construct organic matter from inorganic (Gr. autos=self, trophein=to nourish).

BIOCHEMICAL OXYGEN DEMAND (BOD). The decrease in oxygen content in mg/1 or ppm of a sample of water in the dark at 20°C and as a rule the oxygen demand is measured after 5 days and results from the bacterial breakdown of organic matter and oxidation of certain compounds.

ECOLOGY. The branch of biology that deals with the interrelationships of living organisms and their environments, and to each other.

HETEROTROPH (HETEROTROPHIC). Organisms that are dependent on organic matter for food.

MICROORGANISM. Any minute organism invisible or barely visible to the unaided eye, such as, bacteria, many algae, protozoa, and many fungi.

NON-REFRACTORY. Yield readily to treatment, easily oxidized and broken down.

PHOTOSYNTHESIS. The process by which simple sugars are manufactured from carbon dioxide and water by living plant cells with the aid of chlorophyll in the presence of light.

SAPROBE (SAPROPHYTE). Any organism living on dead or decaying organic matter.

SIGNIFICANCE. Used only in connection with statistics, and in general, it is used in connection with the rejection of a hypothesis and observable variations that cannot be explained by the use of a confidence interval.

TURBIDITY. The degree of opaqueness produced in water by suspended particulate matter which in turn is generally responsible for water color quality, and the concentration of substances, if sufficiently high, determines the transparency of the water by limiting the light transmission within it.

TABLE 1A. The abundance of bacteria in the anaerobic stabilization pond during June and July, 1970, for seven stations.

STATION	(PLATES)	17 June	24 June	8 July	22 July
1	1	54	206	100	208
	2	59	203	104	120
	3	56	214	106	110
	Mean	56x10^5	208x10^4	103x10^5	170x10^5
2	1	340	93	70	160
	2	280	88	80	150
	3	280	99	85	135
	Mean	300x10^4	93x10^4	78x10^5	148x10^5
3	1	86	38	420	100
	2	118	70	400	100
	3	108	62	420	120
	Mean	104x10^4	57x10^4	413x10^4	106x10^5
4	1	73	56	250	55
	2	98	36	380	60
	3	99	52	400	50
	Mean	90x10^4	48x10^4	343x10^4	55x10^5
5	1	102	225	240	42
	2	75	180	250	65
	3	66	300	230	65
	Mean	81x10^4	235x10^3	240x10^4	57x10^5
6	1	61	320	420	380
	2	51	350	350	390
	3	44	360	270	400
	Mean	52x10^4	343x10^3	346x10^4	390x10^4
7	1	45	150	300	290
	2	40	134	310	270
	3	38	160	165	280
	Mean	41x10^4	148x10^3	258x10^3	280x10^4

TABLE 2A. The abundance of algae in the anaerobic stabilization pond during June and July, 1970, for seven stations.

STATION	SPECIES OR GROUP	ALGAL CELLS/ML				
		17 June	24 June	8 July	22 July	28 July
1	Chlorophytes & Others	810	530	1690	6990	----
	Diatoms	290	530	370	200	----
	Oscillatoria rileyi	20	140	0	140	----
	TOTAL	1120	1200	2060	7330	----
2	Chlorophytes & Others	2240	810	2680	43280	----
	Diatoms	300	370	630	450	----
	Oscillatoria rileyi	50	200	0	60	----
	TOTAL	2590	1380	3310	43790	----
3	Chlorophytes & Others	4570	710	3640	139800	----
	Diatoms	710	370	450	530	----
	Oscillatoria rileyi	20	140	0	200	----
	TOTAL	5300	1220	4090	140530	----
4	Chlorophytes & Others	2240	630	5510	299500	----
	Diatoms	710	370	630	730	----
	Oscillatoria rileyi	30	60	10	60	----
	TOTAL	2980	1060	6150	299930	----
5	Chlorophytes & Others	5180	920	6950	522900	----
	Diatoms	710	530	530	370	----
	Oscillatoria rileyi	0	60	0	0	----
	TOTAL	5890	1510	7480	523270	----
6	Chlorophytes & Others	3560	710	5510	698800	----
	Diatoms	710	630	530	370	----
	Oscillatoria rileyi	0	140	0	0	----
	TOTAL	4270	1480	6040	699170	----
7	Chlorophytes & Others	5180	1280	1540	960300	1800000
	Diatoms	710	710	1850	370	1000
	Oscillatoria rileyi	0	200	0	0	0
	TOTAL	5890	2190	3390	960670	1801000

TABLE 3A. Secchi disc transparency and water temperature profiles in the anaerobic stabilization pond during June and July, 1970 for seven stations.

June 17, 1970--1:30 p.m.	STATION NUMBERS AND TEMPERATURE °F						
Depth (feet)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	76	75	75	76	76	76	76
1	76	75	74	76	76	76	76
2	76	75	74	74	76	76	76
3	76	75	74	74	76	75	76
4	75	74	74	74	74	74	
5	75	74	74	74	74	74	
6	74	74	74	74	73	74	
7	74	74	74	74	73	74	
Secchi Disc (inches)	12	13	12	12	16	16	14
June 24, 1970--10:15 a.m.							
0	74	74	74	74	74	75	75
1	74	74	74	74	74	75	75
2	74	74	74	74	74	75	75
3	74	74	74	74	74	75	75
4	74	74	74	74	74	75	
5	74	74	74	74	74	75	
6	74	74	74	74	74	74	
7	74	74	74	74	74	74	
Secchi Disc (inches)	12	12	12	12	12	12	12
July 8, 1970--9:30 a.m.							
0	74	74	74	74	74	74	74
1	74	74	74	74	74	74	74
2	74	74	74	74	74	74	74
3	74	74	74	74	74	74	74
4	74	74	74	74	74	74	
5	74	74	74	74	74	74	
6	74	74	74	74	74	74	
7	74	74	74	74	74	74	
Secchi Disc (inches)	12	11	11	11	13	12	13
July 22, 1970--10:00 a.m.							
0	76	76	76	76	76	76	76
1	76	76	76	76	76	76	76
2	76	76	76	76	76	76	76
3	76	76	76	76	76	76	76
4	76	76	76	76	76	76	
5	76	76	76	76	76	76	
6	76	76	76	76	76	76	
7	76	76	76	76	76	76	
Secchi Disc (inches)	11	11	12	12	11	11	12

TABLE 4A. Systematic list of the biota found on surface stones of the biological (trickling) filters and from the surface to 7 feet in the anaerobic stabilization pond during June and July, 1970.

GENERAL GROUP	SPECIES OR GENUS	HABITAT
1. BACTERIA		
	Sphaerotilus natans	FS 1/
	Zoogloea ramigera	FS
	Beggiatoa sp.	FS
	Thiothrix sp.	FS
	Chromatium sp.	AP 2/
2. FUNGI		
Fungi-Imperfecti	*Geotrichum candidum* Link. ex Pers. emend. *Carmichael*	FS
3. ALGAE		
Chlorophyta (green algae)		
Volvocales		
Spondylomoraceae	*Pyrobotrys gracilis* (Korsch.)	AP
Chlamydomonaceae	*Chlamydomonas sp.*	FS+AP
Ulotrichales		
Ulotrichaceae	*Ulothrix sp.*	FS 3/
	Uronema sp.	FS 4/
Chlorococcales		
Oocystaceae	*Palmellococcus miniatus* (Kutz.)Chodat	AP
	P. protothecoides (Kruger)Chodat	AP
	Chlorella vulgaris Beijerinck	FS+AP
	C. ellipsoidea Gerneck	AP
	Ankistrodesmus falcatus (Corda) Ralfs var. *acicularis* (A. Braun)	AP
Chlorococcaceae	*Chlorococcum sp.*	FS 5/
Scenedesmaceae	*Scenedesmus acuminatus* (Lag.) Chodat var. *minor* G. M. Smith	FS+AP
Zygnematales		
Desmidiaceae	*Closterium* sp.	AP

1/ Filter stones on surface of biological filters (FS)

2/ Anaerobic stabilization pond (AP)

3/-4/ and 5/ sent to experts for identification, these particular species are not listed in the flora of this region and are presently in liquid and agar culture for further examination.

SYSTEMATIC LIST OF THE BIOTA (Continued)--

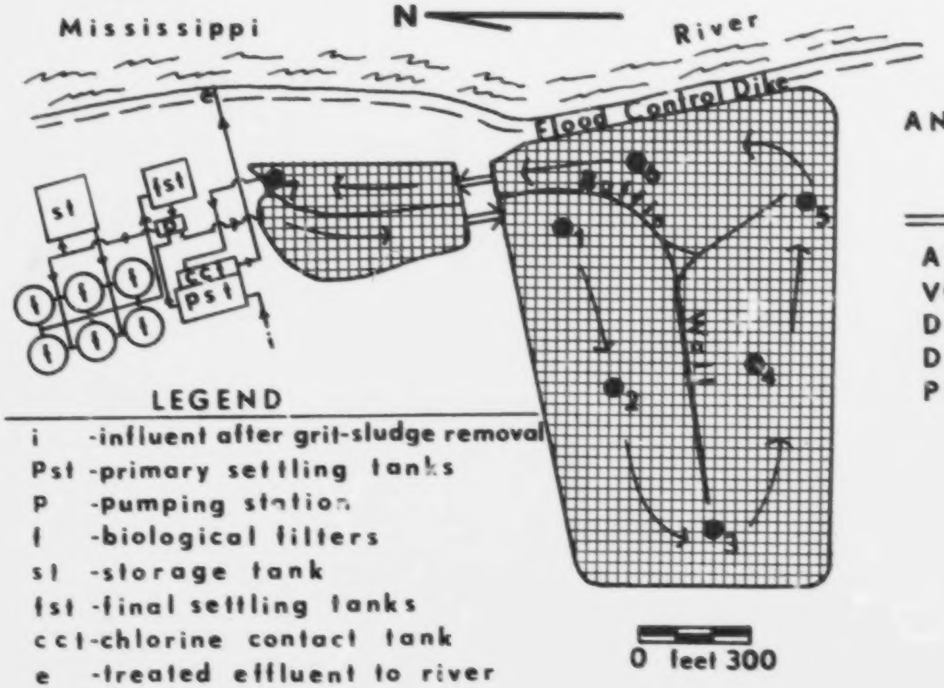
GENERAL GROUP	SPECIES OR GENUS	HABITAT
Euglenophyta (euglenoids)		
Euglenaceae	Euglena gracilis Klebs	AP
Myxophyta (Cyanophyta, blue-green algae)		
Hormogonales (Oscillatoriales)		
Oscillatoriaceae	Oscillatoria rileyi Drouet	AP
	O. geminata Meneghini	FS
	Phormidium sp.	FS
Chroococcales		
Chroococcaeceae	Anacystis marina (Hansgirg) Drouet and Dailey	FS
Chrysophyta (yellow-brown algae)		
Bacillariophyceae		
Pennales	Nitzschia palea (Kutz.) W. Smith	FS+AP
	Hantzschia amphioxus (Ehr.) Grun.	AP
	Navicula gregaria Donkin	FS
	Fragillaria sp.	AP
	Diatoma vulgare Bory	AP
	Surirella angustata Kutz.	AP
	Gomphonema olivaceum (Lyngbye)Kutz.	AP
	Pinnularia sp.	AP
	Synedra ulna (nitzsch) Ehr.	AP
	Cymatopleura solea (Brebisson) S.Smith	AP
	Caloneis amphisbaena (Bory) Cleve	AP
Centrales	Melosira granulata (Ehr.) Ralfs	AP
	Cyclotella Meneghiniana Kutz.	AP
	Stephanodiscus niagarae Ehr.	AP
4. PROTOZOA (single celled animals)		
Ciliata	Colpoda sp.	FS+AP
	Epistylis rotans Svec.	FS
	Vorticella sp.	AP
	Euplotes sp.	AP
	Stylonychia sp.	AP
	Lionotus sp.	AP
Sarcodina	Valkampfia sp.	AP
5. ZOOFLAGELLATES (flagella locomotion, no chlorophyll)		
	Bodo sp.	AP
	Oicomonas Ocellata	AP
	Anthophysa vegetans (O.F. Muller) Stein	AP
	Gyromonas ambulans Seligo	AP

SYSTEMATIC LIST OF THE BIOTA (Continued)--

GENERAL GROUP	SPECIES OR GENUS	HABITAT
6. NEMATODA (pseudocoelomate round worms)		
	unidentified nematode	FS
7. ARTHROPODA		
Insecta		
Diptera		
Psychodidae	*Psychoda alternata* Say	FS
Crustacea		
Cladocera		
Daphnidae	*Moina sp.*	AP 6/

6/ Observed during the late July algal bloom when dissolved oxygen was detected in the anaerobic stabilization pond. The specimen was sent to an expert for species identification since it was not listed in the fauna of this area.

SOUTH ST. PAUL, MINNESOTA, WASTEWATER TREATMENT PLANT



LEGEND

i	-influent after grit-sludge removal
Pst	-primary settling tanks
p	-pumping station
f	-biological filters
st	-storage tank
fst	-final settling tanks
cct	-chlorine contact tank
e	-treated effluent to river

ANAEROBIC STABILIZATION POND ▦

AREA	27.4 acres
VOLUME	240 acre-ft.
DEPTH (maximum)	8.5 ft.
DEPTH (mean)	6.5 ft.
PERIMETER	6100 ft.

● sample stations

FIGURE 1A.

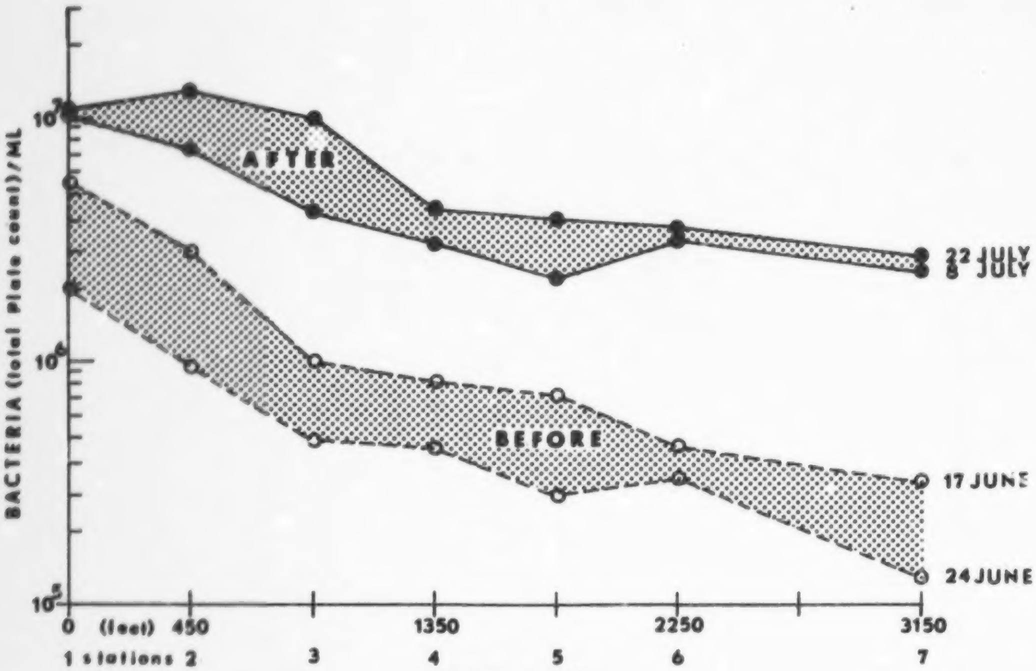


FIGURE 2A.

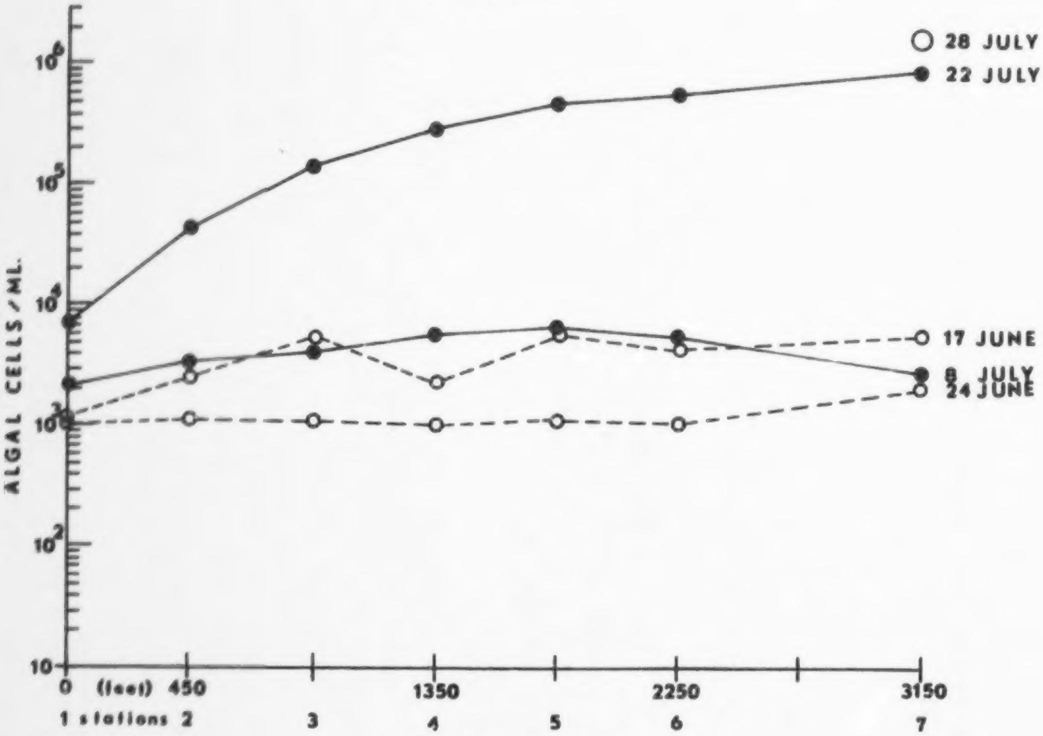


FIGURE 3A.

DESCRIPTION OF BIOTA ILLUSTRATIONS FOR PLATE I.

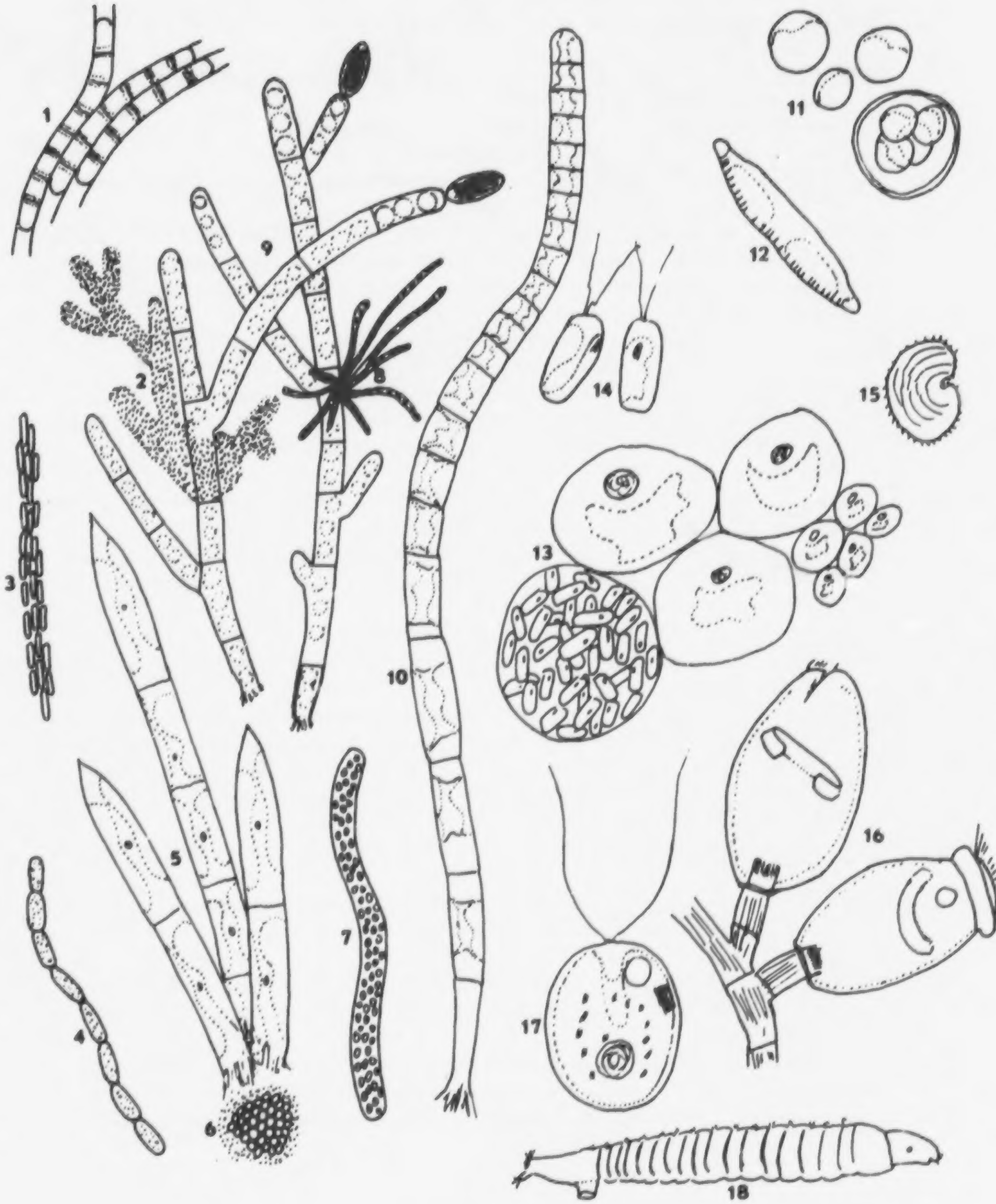
1. *Phormidium sp.* Common blue-green alga, shows several filaments, sheaths confluent, apical cells rounded to obtuse conical.
2. *Zoogloea ramigera*. Very abundant slime colonial bacteria covering the entire filter stone, shows cells within a mucilage secreted by Zoogloea, attached to a fungus filament.
3. *Sphaerotilus natans*. Uncommon on the filter stones observed, shows many cells attached forming a filament.
4. *Oscillatoria geminata* Meneghini. Common glue-green alga, shows a typical filament with constricted cross walls.
5. *Uronema sp.* Common attached green alga, shows three filaments with pointed terminal cells, cup-shaped perital chloroplasts, and basal attachment cells.
6. *Anacystis marina* (Hansgirg) Drouet and Dailey. Common blue-green alga attached to filter stones, usually forming a dense bright blue-green mass of cells, illustration shows a portion of a colony with surrounding secreting mucilage.
7. *Beggiatoa sp.* Commonly observed motile sulfur bacteria, shows a filament with sulfur globules.
8. *Thiothrix sp.* Commonly observed non-motile sulfur bacteria, shows a "colony" attached to a fungus cell with sulfur globules.
9. *Geotrichum candidum* Link. ex Pers. emend. Carmichael. Very abundant filamentous Fungi-Imperfecti attached to filter stones, shows two septate filaments with two exogenous conidia.
10. *Ulothrix sp.* Common filamentous green alga, shows single filament with cup shaped perital chloroplasts, hold-fast basal cell, and smaller terminal cells when compared to long basal cells.
11. *Chlorella vulgaris* Beijerinck. Frequently observed coccoid alga, shows three cells with perital cup chloroplasts, and reproductive mother with four non-motile daughter cells.
12. *Nitzschia palea* (kutz.) W.Smith. Very common yellow-brown alga (diatom) on surface filter stones, shows a single cell.
13. *Chlorococcum sp.* Very common coccoid green alga, responsible for the green appearance of surface filter stones, shows coenobia of nine cells with many motile zoospores in one, and small opening of perital chloroplast with single pyrenoid.
14. *Chlorococcum sp.* Shows a mature, bi-flagellated zoospore with eye pigment spot.
15. *Colpoda sp.* Frequently observed ciliate protozoan, shows characteristic "bean" shape of this species.
16. *Epistylis rotans* Svec. Very common sessile, stalked, protozoan, found attached to the posterior end of *Psychoda* mostly, shows two animals on striated and segmented stalk.

DESCRIPTION OF BIOTA ILLUSTRATIONS FOR PLATE I. (Continued)--

17. *Chlamydomonas sp.* Uncommon on the filter stones observed, shows a single cell with two flagella, eye pigment spot, and perital cup chloroplast.

18. *Psychoda alternata* Say. Very common "filter fly" larva, always observed within the mucilage and fungus filaments, shows a single segmented larva.

PLATE 1. BIOLOGICAL FILTER BIOTA



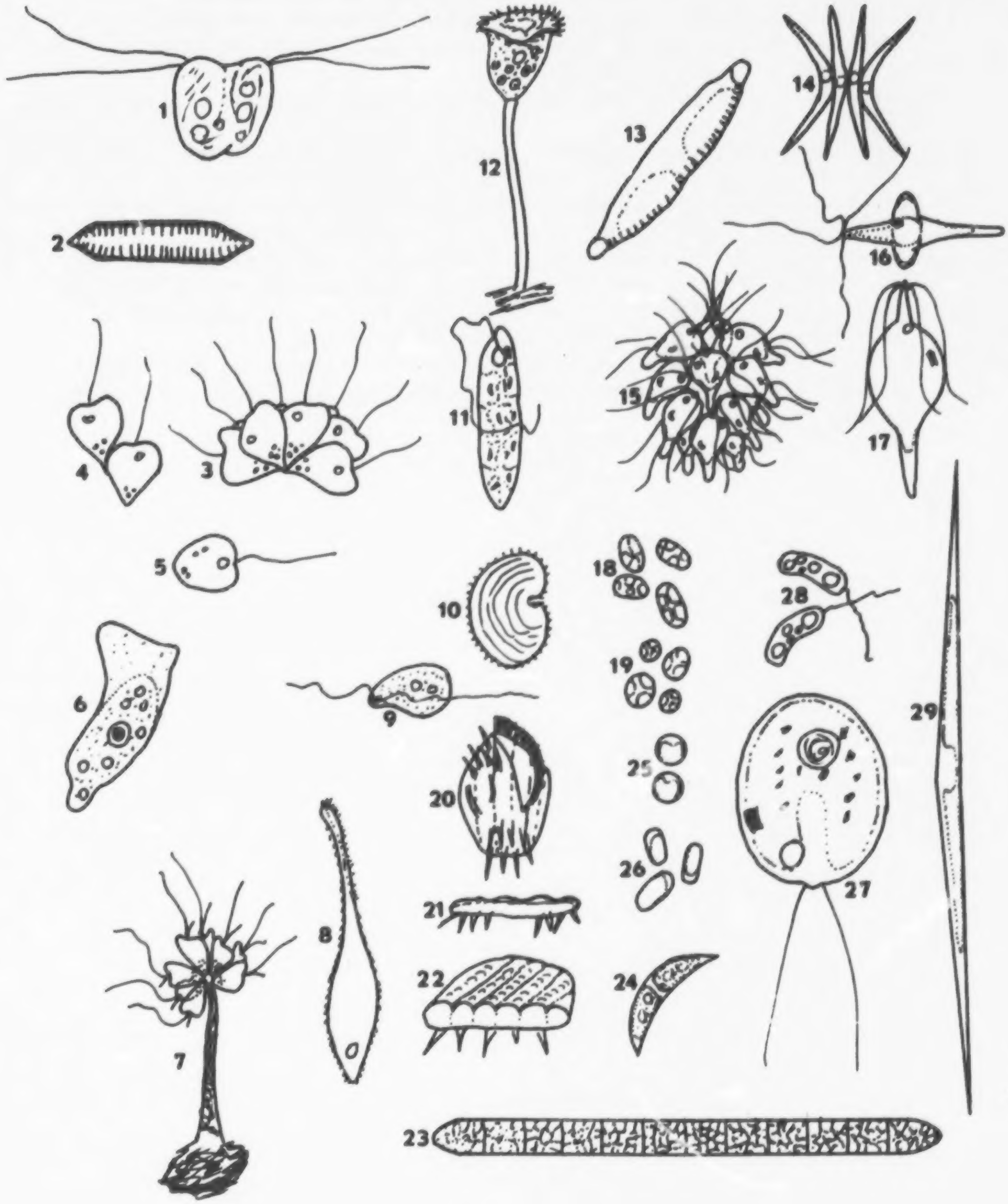
DESCRIPTION OF BIOTA ILLUSTRATIONS FOR PLATE II.

1. *Gyromonas ambulans* Seligo. Uncommon zooflagellate, shows single cell with four flagella.
2. *Surirella angustata* Kutz. Frequently observed diatom, shows single cell.
3. *Oicomonas ocellata.* Common colonial zooflagellate, shows colony with one flagella per cell.
4. *Oicomonas ocellata.* Shows two cells attached.
5. *Oicomonas ocellata.* Shows single, more rounded cell.
6. *Valkampfia sp.* Frequently observed amoeba, shows single cell with large pseudopod or "foot".
7. *Anthophysa vegetans* (O.F. Muller) Stein. Common colonial, stalked, zooflagellate, shows colony with unequal flagella, and stalk.
8. *Lionotus sp.* Frequently observed ciliate protozoan, shows single cell.
9. *Bodo sp.* Commonly observed zooflagellate, shows single cell with one anterior and one posterior trailing flagellum.
10. *Colpoda sp.* Common ciliate protozoan, shows single animal.
11. *Euglena gracilis* Klebs. Frequently observed flagellated alga, shows single cell with long flagellum and plate-to-cup shaped chloroplasts.
12. *Vorticella sp.* Uncommon stalked ciliate protozoan, shows animal with stalk attached to substrate.
13. *Nitzschia palea* (Kutz.) W. Smith. Most common diatom observed in the pond, shows single cell with characteristic markings on the frustule.
14. *Scenedesmus acuminatus* (Lag.) Chodat var. minor G. M. Smith. Frequently observed green alga, shows characteristic attachment of four cells.
15. *Pyrobotrys gracilis* (Korsch.) Commonly observed colonial green alga, shows typical colony of about 16 cells, bi-flagellated.
16. *Pyrobotrys gracilis* (Korsch.) Incorrectly called *Chlorobrachis gracillima* but is a zygote of *Pyrobotrys*, shows four flagella and torpedo-shape.
17. *Pyrobotrys gracilis* (Korsch.) Full grown zygote without lateral arms.
18. *Palmellococcus protothecoides* (Kruger) Chodat. Common coccoid green alga shows oval shape of cells and lobes of perital chloroplast.
19. *Palmellococcus miniatus* (Kutz) Chodat. Common coccoid green alga, shows spherical shape of cells and lobes of perital chloroplast.
20. *Euplotes sp.* Frequently observed ciliate protozoan, shows characteristic shape of the animal and cirri-like "feet".
21. *Euplotes sp.* Side view, shows how this animal can walk with its cirri, or modified cilia.

DESCRIPTION OF BIOTA ILLUSTRATIONS FOR PLATE II. (Continued)--

22. *Euplotes sp.* Cross section of the animal showing dorsal ridges.
23. *Oscillatoria rileyi* Drouet. Also keys out to Schizothrix calcicola (Agardh) Gomont from Drouet's latest revision. Frequently observed highly gas vacuolated single planktonic filaments, shows single filament.
24. *Closterium sp.* Uncommon desmid, shows cresent shaped cell with two chloroplasts.
25. *Chlorella vulgaris* Beijerinck. Common coccoid green alga, shows single cells with perital cup chloroplasts.
26. *Chlorella ellipsoidea* Gerneck. Common coccoid green alga, shows oval shape of cells with perital cup chloroplasts.
27. *Chlamydomonas sp.* Uncommon bi-flagellated green alga in the pond, shows single cell, eye pigment spot, and perital cup chloroplast.
28. *Chromatium sp.* Commonly observed motile sulfur bacteria, shows single cells with flagella and sulfur globules.
29. *Ankistrodesmus falcatus* (Corda) Ralfs var. *acicularis* (A. Braun). Frequently observed green alga, shows long cell with pointed ends.

PLATE 11. ANAEROBIC STABILIZATION POND BIOTA



APPENDIX B

EXPLANATION OF THE SOURCE OF WASTE FERRIC CHORIDE SOLUTION USED IN FLOCCULATION TESTS AT THE SOUTH ST. PAUL SEWAGE TREATMENT PLANT
JULY, 1969 to SEPTEMBER, 1969

This ferric chloride solution waste is generated at Buckbee Mears Manufacturing Company in St. Paul during the dissolving of steel sheets to make television screens, electric shaver heads, steel sieves, and other items where small uniform high density holes in steel plate are needed.

In the process for making television screens (which is typical for the other items), the sheet metal to be used is coated with a substance resistant to ferric chloride and the image of the television screen with the millions of holes is printed with heat and light on this coating. This printing step removes the coating for each hole down to bare metal. The sheet metal is then run through a strong 146°F ferric chloride solution fortified with muriatic acid.
A continuous testing of the solution is carried out and as the ferrous iron content gets above certain limits, chlorine gas is added along with water. During testing, if certain conditions prevail, some muriatic acid is also added; these additions bring up the ferric chloride content to the proper level for uniform rapid etching. This addition of iron (the iron etched away from the sheets of steel) the muriatic acid to furnish Cl_2 ions, the chlorine gas and the water keeps converting the raw iron to ferric chloride and thus keeps increasing the volume to a point that several hundred gallons of excess ferric chloride waste is being generated daily. This waste is then pumped over to other etching tanks for etching stainless steel sheet (nickle, chrome, steel) and cooper plate. Again, when the ferric chloride is spent in these etching tanks, it is dumped into large holding tanks for ultimate disposal. Due to the large size, a fairly uniform waste product is produced.

At the present time, this ferric chloride waste is being hauled by tank truck to the Metropolitan Sewage Treatment Plant to be utilized as a supplemental supply of ferric chloride sludge conditioning. This solution has an active $FeCl_3$ content of approximately 45% (See analytical data of representative sample tested by the Twin City Testing Laboratories).

At present, as far as can be determined, there are only two other sources of this waste material and they both are manufacturers of tv screens. However, there are places such as the branch office in Chicago of the company from which we get our testing material where the demand for ferric chloride etching at present is insufficient to justify putting in the chloride rejuvenating equipment. In these cases the spent ferric chloride is a serious waste problem. Since the pH of this waste is low enough to be very corrosive to sewers, in some communities these wastes are being prohibited entrance to the city sewers.

It is conceivable that now that this method of etching holes and slots in steel has been developed to exact a science that many other items where minute holes are made in metal will be manufactured in this manner which will increase the amount of this waste and therefore its availability.

645-3601

TWIN CITY TESTING AND ENGINEERING LABORATORY, INC.

ENGINEERS AND CHEMISTS
662 Cromwell Avenue - St. Paul, Minn. 55114

REPORT OF: CHEMICAL EXAMINATION

PROJECT:

DATE: September 19, 1969

REPORTED TO: Sewage Disposal System
South St. Paul, Minnesota 55075
(8) Attn: Mr E. D. Larson

FURNISHED BY:

COPIES TO:

LABORATORY No. 2-10353

SAMPLE IDENTIFICATION: Ferric Chloride Solution

TESTS AND RESULTS:

Ferric Chloride as $FeCl_3$ (percent)	=	44.90
Nickel as Ni (percent)	=	0.24
Manganese as Mn (percent)	=	Less than 0.01
Molybdenum as Mo (percent)	=	0.03
Calcium as Ca (percent)	=	Nil
Cobalt as Co (percent)	=	0.04
Copper as Cu (percent)	=	0.0002

REMARKS: Sample received September 15, 1969.

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Twin City Testing and Engineering Laboratory, Inc.
By

APPENDIX C

SLUDGE CHARACTERISITICS

In November and December of 1969 chemical treatment tests were made on separated industrial and domestic wastewater received at the South St. Paul sewage treatment plant using a dual system of ferric chloride and Dow A-23. During this time some sludge studies were run to determine if the characteristics of the sludge produced by the chemical treatment process were changed in any way.

The characteristics of sludge tested were percent moisture, percent volatile solids, heat of combustion, filterability, and digestion characteristics.

Sludge samples were taken of sludge from both the test and control tanks. Grab samples of sludge were taken several times a day on those days when sampling was being done. Samples of the test and control tank were taken at approximately the same length of time after pumping of the tank had started. Sludge samples were taken from a pit from which the sludge was pumped. The sludge was pumped from the bottom of the pit and flowed into the pit through a pipe near the top. Samples were taken of sludge as it fell from the pipe into the pit. A large enough number of grab samples of sludge were taken to average out individual differences between the test and control tanks and produce a reliable average.

Percent moisture, percent volatile and filterability tests were run on grab samples. Heat of combustion and digestability were run on composite samples made of equal proportions of grab samples taken for the day on which the test was run.

The percent moisture test was made by drying an approximate 100 g sample of sludge overnight at 105°C in a drying oven. Volatile solids were run by igniting the dried sludge sample at 600°C. until all the organic matter was volatized.

Heat of combustion tests were run using a Parr peroxide bomb colorimeter. Each sample on which the heat of combustion was run was prepared from one liter of the composite sample taken from total composite sample for the day after thorough mixing. The one liter sample was dried in a 105°C oven. It was then ground to a fine powder by mixing it dry in a blender run at high speed. An approximately sized sample of this was taken and weighed for the actual test.

Digestion characteristics of the sludge were tested using scale model digestors. Two digestors were used for sludge from the test tank and two digestors were used for sludge from the control tank. Each digestor unit consisted of two stages.

The individual stages consisted of five gallon polyethylene bottles The first stage was stirred continuously by an electric stirring device to provide thorough mixing throughout. The second stage was quiescent which allowed the sludge to separate from the supernatant. The first stage was provided with a sludge inlet tube, a sludge withdrawal tube, a mechanical stirring device with a water seal, and a gas line to the gas collection unit. This unit consisted of two three gallon glass carboys. The first carboy was filled with water. The gas from the digestor entered this and displaced water into the second one where its displaced volume could be measured thus affording an accurate method for measuring the volume of gas produced. Both the first and second stages of all four digestores were immersed in a constant temperature water bath held at 35° ± 1.0°C. All four digestors were identical in design.

The digestors were run for a period of over a year on primary sludge from wastewater to which no chemicals had been added. This produced a state of equilibrium of constant digestion, gas production and digestor pH. Determined by the digestors tests were cubic feet of gas produced per pound of volatile material destroyed and percent of the volatile material which was digested. Parameters measured directly were gas produced by each stage, percent moisture and percent volatile solids of the sludge added to the first stage and sludge removed from the first and second stages as well as the supernatant removed from the second stage. The pH was also measured on the influent and the effluent of both stages and the supernatant to insure consistancey of operation. See Tables C66-C72.

The results of the percent moisture analysis for the sludge produced by the industrial wastewater are shown in Table C61. The average percent moisture for the test tank sludge was 96.2%, while the control tank sludge showed a percent moisture of 95.5%. The average percent volatile solids of the test tank sludge was 76.2% compared to 76.1% for the control tank sludge. Apparently the addition of chemicals to separate industrial wastewater had no effect on the percent moisture or percent volatile solids of the sludge as it was removed from the settling tanks.

The percent moisture and percent volatile solids content of the sludge produced during tests on domestic wastewater are shown in Table C62. The average percent moisture of the sludge removed from the test tank was 95.6% while the average percent moisture of the sludge removed from the control tank was 94.5%. The average percent volatile solids of the sludge removed from the test tank was 80.7%, while the average percent volatile solids removal from the control tank was 82.8%. Again on tests on separated domestic wastewater there was no large difference indicated between sludge samples taken from the test and control tanks in terms of percent moisture or percent volatile solids.

The results of heat or combustion tests are given in Table C63. During the period of testing of industrial wastewater the average heat of combustion of sludge taken from the test tank was 9,922 Btu per pound while the value of sludge taken from the control tank was 9,102 Btu per pound. Considering the number of samples run and variation between samples, the average of the results are of the same order.

Filterability of the sludge was tested using the buchner funnel method. Two hundred ml of sludge was filtered through a number one Whatman filter paper in a nine cm buchner funnel. The volume of filtrate and the length of time required to draw enough water out of the sample to break the vacuum were measured. The percent moisture remaining in the filter cake was determined. The results of filterability tests on sludge samples taken during industrial wastewater tests are given in Table C64. There was no significant change in the average ml of filtrate for the test and control tank sludges nor was there any significant difference in the percent moisture remaining in the filter cake of the test and control tank sludges.

There was observed, however, a significant difference in the time of filtration between the test and control tank sludges. Contrary to what might be expected, the filtration time of the sludge taken from the test tank was substantially greater than that taken from the control tank. The average filtration time for the test tank sludge was 53 mintues, while the average filtration time of the control tank sludge was 24 minutes.

The results of the filtration tests run on sludge taken during the testing of chemical treatment on domestic wastewater are given in Table C65. Again there was no large difference in the volume of filtrate. The filtration time for the domestic sludge from the test tank was 33 minutes and the filtration time for the sludge from the control tank was 29 minutes. This is not as large a difference as observed in tests of chemical treatment of industrial wastewater and is not as meaningful an indication of poorer filterability characteristics. An explanation of the fact that a much longer time was required for the filtration of test tank sludge as compared to the control tank sludge during the industrial period was that ferric chloride was added to the wastewater at a dosage of 50 mg/l during the test on industrial waste while during the greater part of the tests on the domestic waste only 20 mg/l of ferric chloride was being added to the wastewater.

The data collected for sludge digestion tests is shown in Tables C66 through C72. A summary of the results of the sludge digestion tests for sludge taken during the industrial test period are shown in Table C66.

The volume of gas generated per pound of volatile solids destroyed for the test tank was somewhat less than that generated per pound of volatile solids destroyed for the control tank. Considering the limited amount of data collected and the fact that slightly greater amounts of volatile solids were added to the control digestors these results are felt to be somewhat inconclusive, but they do indicate the results of the chemicals did not have a substantial detrimental effect on the operation of the digestors.

In terms of percent volatile material destroyed the digestors operated on sludge from the control tanks showed a reduction of 68.3% of volatile solids. Again considering that a somewhat higher amount of volatile solids were added to the control digestors this lower pecent reduction is somewhat inconclusive. Again the data indicates the digestores were not substantially inhibited.

A summary of the results of the digestor tests on sludge obtained during trials of domestic wastewater are given in Table C67. The volume of gas production per pound of volatile materials destroyed was greater for sludge taken from the test tank in this case. Again, considering the limited number of test days it was not felt the results were conclusive but again were indicative that the chemicals did not have an inhibitory effect on the digestion process.

In terms of percent of volatile materials destroyed the test sludge digestors and contol sludge digestors showed very little difference. The test tank digestor showed a reduction in volatile solids of 74.2% while the control tank digestor showed a reduction of 69.8% volatile solids destroyed. Again this indicated the presence of chemicals in the sludge did not inhibit digestion.

Table C68 gives the characteristics of the sludge added to the digestors. Tables C69 through C72 give characteristics of the sludge and supernatant withdrawn form each of the digestors. While this data is limited, a study of the data indicates that there was no drastic upset of any of the digestors due to the use of chemicals.

The volume of sludge produced during chemical treatment of combined wastewater was approximately 50% greater than produced without the addition of chemicals. When no chemicals were added 120,000 gallons per day of primary sludge was produced in the three sedimentation tanks while with the addition of chemicals about 180,000 gallons per day of sludge were produced.

The following conclusions can be drawn from the tests on sludge: (1) No change was made in the percent moisture and percent volatile solids contents of the waste by the addition of chemicals. (2) The heat of combustion was not substantially effected by the use of chemicals. (3) Addition of ferric chloride to the industrial wastewater in concentrations of 50 mg/l substantially slowed the rate of filtration of the sludge, however, the addition of 20 mg/l of ferric chloride to domestic wastewater had slight effect on the filtration characteristics. (4) The data from the sludge digestion tests were somewhat inconclusive but it did indicate that digestion was not substantially inhibited , nor were the digestors drastically upset by the addition of sludge from sewage treated with the dual system of ferric chloride and organic polyelectrolyte. (5) Sludge volume was increased by about 50% by the addition of chemicals.

Table 61C

Sludge Moisture And Volatile Solids Content
November Industrial Waste

Date 1969	Percent Moisture		Percent Volatile	
	Test	Control	Test	Control
Nov. 3	98.7	94.2	73.8	81.7
	96.4	94.4	80.7	83.6
	97.4	98.6	72.6	77.0
Nov. 4	98.2	95.0	66.8	74.0
	94.2	96.4	77.8	82.7
	96.9	95.2	79.4	83.3
Nov. 5			75.0	83.4
	98.0	94.1	86.3	76.7
	95.7	94.3	81.0	85.1
	95.2	91.8	83.8	86.0
	97.5	94.7	77.0	85.4
Nov. 6	97.3	94.3	76.6	82.2
	97.4	93.6	80.2	82.7
	94.3	95.2	83.7	83.0
Nov. 12	94.4	95.6	77.4	79.8
	97.3	95.2	78.8	82.7
	93.1	95.3	90.0	81.3
Nov. 13	95.8	98.5	76.6	69.3
	94.7	93.9	78.7	80.5
	99.1	95.0	65.8	82.3
Nov. 14	95.7	96.7	77.6	74.5
	95.0	99.6	75.0	48.8
	99.0	99.5	64.3	53.5
Nov. 18	95.5	94.5	77.7	79.4
	98.9	99.6	68.9	50.0
	99.3	99.3	56.8	55.0
Nov. 19	93.5	92.6	67.9	65.6
	96.3	94.4	79.8	82.8
	96.9	94.3	77.2	81.9
	93.7	92.4	75.3	70.0

Table 61 (Continued)

Date 1969	Percent Moisture		Percent Volatile	
	Test	Control	Test	Control
Nov. 20	93.6	99.4	76.0	57.8
	97.0	95.5	76.2	81.9
	96.0	94.8	77.8	80.6
	94.2	94.5	66.3	72.5
Nov. 25	95.8	94.2	79.0	83.2
	94.6	93.8	81.3	80.4
	96.1	97.6	79.3	76.8
Mean	96.2	95.5	76.2	76.1
Standard Deviation	±1.77	±2.14	±6.62	±10.44

Table 62C

Sludge Moisture And Volatile Solids Content
December Domestic Waste

Date 1969	Percent Moisture		Percent Volatile	
	Test	Control	Test	Control
Dec. 1	96.4	95.5	75.2	79.2
	98.8	97.1	76.2	80.5
	96.2	95.2	80.2	84.8
Dec. 9	98.7	93.4	76.6	84.3
	94.7	94.2	84.0	84.7
	95.6	93.5	81.1	84.9
	97.7	93.4	77.2	87.6
Dec. 10	92.7	99.1	83.4	73.8
	93.8	94.3	81.3	80.7
Dec. 11	98.4	95.5	75.0	33.9
	98.5	94.8	78.2	85.7
	96.7	95.1	81.1	85.3
	91.8	91.3	89.9	90.2
Dec. 16	92.7	92.4	91.6	85.6
	93.2	92.2	83.4	85.4
Dec. 17	97.4	92.7	82.2	85.4
	92.4	93.6	85.5	86.9
	99.2	92.4	76.3	85.8
Dec. 23	94.7	99.8	76.0	53.0*
	93.4	95.1	85.0	84.7
	94.7	94.5	85.8	86.3
Mean	95.6	94.5	80.7	82.8
Standard Deviation	±2.42	±2.14	±4.45	±3.80

* Excluded from calculations

Table 63C

Calorific Tests
BTU/LB

Industrial Tests Sludge

Date - 1969	Test Tank	Control Tank
November 18	9,413	8,683
November 19	10,216	9,446
November 20	9,676	7,496
November 26	10,385	10,783
Mean	9,922	9,102
Standard Deviation	± 455	± 1,376

Domestic Waste Sludge

Date - 1969	Test Tank	Control Tank
December 9	10,093	11,074
December 11	11,448	11,712
December 16	11,954	11,059
December 17	11,139	11,264
December 23	12,785	11,650
Mean	11,484	11,352
Standard Deviation	± 971	± 312

Table 64C

Buchner Funnel Tests On Sludge
Industrial Wastewater Tests
A-23 And $FeCl_3$

Date 1969	ML Of Filtrate		Filtration Time Minutes		Filter Cake % Moisture	
	Test	Control	Test	Control	Test	Control
Nov. 3	193	146			66.0	71.6
	189	163			73.0	67.6
Nov. 4	177	154			71.6	72.2
	177	175			69.8	65.0
Nov. 5	191	168			66.0	68.0
	175	167			69.2	62.6
	160	145	105	20	76.7	68.0
	191	168	84	17	67.8	70.0
Nov. 6	178	165	65	23	74.5	70.5
	189	155	64	25	59.5	72.1
	159	185	22	20	72.5	62.2
Nov. 12	163	174	62	28	70.5	67.3
	188	173	60	25	56.0	64.2
	181	171	55	23	66.4	65.9
Nov. 13	167	156	41	32	70.6	72.0
	197	168	21	21	60.2	66.7
	150	182	72	21	85.5	66.2
Nov. 18	176	163	55	35	68.7	71.0
Nov. 19	163	158	36	19	69.9	66.3
	173	155	58	17	70.8	75.6
	185	163	83	20	69.6	73.0
	151	160	43	15	76.1	63.4
Nov. 20	188	171	49	17	64.6	63.4
	165	162	37	13	72.2	73.8
	153	179	58	15	70.0	69.6
	182	167	23	26	57.2	69.8
	154	159	32	25	76.0	70.0
	174	187	43	73	66.8	64.2
Mean	175	166	53	24	69.2	68.2
Standard Deviation	±14.0	±10.6	±21.2	±12.2	±6.1	±3.7

Table 65 C

Buchner Funnel Tests On Sludge
Domestic Wastewater
Treatment $FeCl_3$ And A-23

	ML Of Filtrate		Filtration Time Minutes		Filter Cake % Moisture	
Date 1969	Test	Control	Test	Control	Test	Control
Dec. 1	174	171	70	24	71.0	71.6
	198	187	57	36	62.8	65.2
	178	176	36	34	73.0	67.0
Dec. 9	192	152	12	40	54.8	61.8
	169	160	60	51	68.1	72.2
	170	160	58	20	70.3	70.0
	188	163	38	27	60.4	60.7
Dec. 10	153	194	15	31	78.6	61.8
	154	156	24	30	76.0	75.0
Dec. 11	196	170	20	30	66.0	72.3
	194	165	25	36	49.5	72.2
	184	167	28	19	64.0	73.2
	139	148	13	9	71.2	57.8
Dec. 16	162	148	8	23	64.2	72.8
	156	148	38	39	68.8	69.8
Dec. 17	189	156	30	38	59.5	69.8
	159	164	25	21	68.3	69.9
	199	144	43	26	66.6	71.9
Mean	175	162	33	29	66.2	68.6
Standard Deviation	± 18.3	± 13.1	± 18.2	± 9.8	± 7.3	± 5.0

Table 66C

Gas Production

November Industrial Waste

Digestor		Ave. Volume L/Day	Cu. Ft. For Month	Cu. Ft/Lb Of Volatile Material Lost In Two Stages
Test Sludge # 1	A	13.5	14.3	17.5
	B	3.4	3.6	
Test Sludge # 2	A	16.5	17.5	17.4
	B	1.4	1.5	
Control Sludge # 1	A	16.7	17.7	20.6
	B	4.2	4.5	
Control Sludge # 2	A	19.0	20.2	25.6
	B	7.0	7.4	

Average Test 17.4
Average Control 23.1

Volatile Material Destroyed

Digestor	Vol. Solids Grams Added	Vol. Solids Grams Removed	Vol. Solids Grams Destroyed	% Red.
Test # 1	575	113	462	80.5
Test # 2	575	82	493	85.7
Control # 1	715	227	488	68.3
Control # 2	715	227	488	68.3

Average Of Test 83.1
Average Of Control 68.3

Table 67C

Gas Production

December Domestic Waste

Digestor		Ave. Volume L/Day	Cu. Ft. For 3 Week Period	Cu. Ft/Lb. Of Volatile Material Lost In Two Stages
Test Sludge # 1	A	10.3	8.4	24.7
	B	4.5	3.6	
Test Sludge # 2	A	19.5	15.9	34.1
	B	2.9	2.4	
Control Sludge # 1	A	11.6	9.4	13.4
	B	.7	.6	
Control Sludge # 2	A	21.1	17.2	24.1
	B	4.9	4.0	

Average Of Test 29.4
Average Of Control 18.7

Volatile Material Destroyed

Digestor	Vol. Solids Grams Added	Vol. Solids Grams Removed	Vol. Solids Grams Destroyed	% Red.
Test # 1	310	90	220	70.1
Test # 2	310	67	243	78.4
Control # 1	526	189	337	64.1
Control # 2	526	128	398	75.6

Average Of Test 74.2
Average Of Control 69.8

Table 68C

Raw Sludge To Digestors

November Industrial Wastewater

	Test Tank Sludge			Control Tank Sludge		
Nov. 1969	Percent Moisture	Percent Volatile	pH	Percent Moisture	Percent Volatile	pH
13	96.4	78.3	6.02	95.4	80.3	6.21
19	97.9	72.6	6.32	96.8	76.6	6.43
26	95.5	80.0	5.96	95.5	80.7	5.95
Ave.	96.6	77.0		95.9	79.2	

December Domestic Wastewater

	Test Tank Sludge			Control Tank Sludge		
Dec. 1969	Percent Moisture	Percent Volatile	pH	Percent Moisture	Percent Volatile	pH
2	97.0	77.0	6.12	96.2	80.8	6.20
10	96.8	80.8	6.20	93.5	85.0	5.81
18	95.8	83.7	6.00	93.2	85.6	5.80
Ave.	96.5	80.5		94.3	83.8	

Table 69C

Sludge Digestors

Test Tank Sludge
Industrial Wastewater
Digestor # 1

	1st Stage Sludge			2nd Stage Sludge			2nd Stage Supernatant		
Nov. 1969	Percent Moisture	Percent Volatile	pH	Percent Moisture	Percent Volatile	pH	Percent Moisture	Percent Volatile	pH
13	97.7	72.8	6.89	97.1	64.4	7.22	99.6	51.0	7.58
19	98.7	64.2	7.29	97.9	61.6	7.36	99.2	50.0	7.53
26	97.9	72.2	6.90	96.9	66.4	7.12	99.6	43.8	7.60
Ave.	98.1	69.7		97.3	64.1		99.5	48.3	

Digestor # 2

	1st Stage Sludge			2nd Stage Sludge			2nd Stage Supernatant		
Nov. 1969	Percent Moisture	Percent Volatile	pH	Percent Moisture	Percent Volatile	pH	Percent Moisture	Percent Volatile	pH
13	99.4	51.5	7.50	98.2	60.0	7.39	99.6	47.0	7.50
19	98.8	56.0	7.42	97.7	60.2	7.50	99.6	36.5	7.50
26	97.8	60.8	7.53	97.2	59.7	7.52	99.6	29.5	7.61
Ave.	98.7	56.1		97.7	59.9		99.6	37.7	

Table 70C

Sludge Digestors

Control Tank Sludge
Industrial Wastewater
Digestor # 1

	1st Stage Sludge			2nd Stage Sludge			2nd Stage Supernatant		
Nov. 1969	Percent Moisture	Percent Volatile	pH	Percent Moisture	Percent Volatile	pH	Percent Moisture	Percent Volatile	pH
13	95.7	73.2	7.29	95.8	71.8	7.33	95.4	66.7	7.50
19	98.9	68.5	7.27	95.8	65.0	7.46	99.5	35.0	7.50
26	98.8	65.8	7.25	97.5	62.5	7.50	99.6	43.9	7.62
Ave.	97.8	69.2		96.4	66.4		98.2	48.5	

Digestor # 2

	1st Stage Sludge			2nd Stage Sludge			2nd Stage Supernatant		
Nov. 1969	Percent Moisture	Percent Volatile	pH	Percent Moisture	Percent Volatile	pH	Percent Moisture	Percent Volatile	pH
13	96.6	72.8	7.03	96.2	66.3	7.15	98.2	65.6	7.41
19	97.8	69.2	7.30	96.9	65.8	7.00	98.9	60.0	7.32
26	97.3	73.6	6.98	96.6	65.6	7.38	97.2	66.7	7.30
Ave.	97.2	71.9		96.6	65.9		98.1	64.1	

Table 71C

Sludge Digestors

Domestic Wastewater
Test Tank Sludge
Digestor # 1

	1st Stage Sludge			2nd Stage Sludge			2nd Stage Supernatant		
Dec. 1969	Percent Moisture	Percent Volatile	pH	Percent Moisture	Percent Volatile	pH	Percent Moisture	Percent Volatile	pH
2	99.2	47.0	7.40				99.5	40.5	7.62
10	97.4	75.3	6.83	95.0	63.4	7.30	99.4	44.5	7.71
18	96.3	81.3	6.50	95.7	56.5	7.20	99.2	53.5	7.70
23	98.3	73.4	7.35	97.9	63.5	7.58	99.3	54.0	7.61
Ave.	97.8	69.3		96.2	61.1		99.5	48.1	

Digestor # 2

	1st Stage Sludge			2nd Stage Sludge			2nd Stage Supernatant		
Dec. 1969	Percent Moisture	Percent Volatile	pH	Percent Moisture	Percent Volatile	pH	Percent Moisture	Percent Volatile	pH
2	99.4	44.8	7.47	95.6	55.4	7.53	99.6	32.5	7.56
10	99.6	43.0	7.70	97.3	56.7	7.62			7.67
18	99.4	43.8	7.60	95.6	61.7	7.40	99.6	38.4	7.49
23	99.1	52.7	7.52	98.5	47.3	7.60	99.5	39.0	7.60
Ave.	99.4	46.1		96.7	55.3		99.6	36.6	

Table 72C

Sludge Digestors

Domestic Wastewater
Control Tank
Digestor # 1

	1st Stage Sludge			2nd Stage Sludge			2nd Stage Supernatant		
Dec. 1969	Percent Moisture	Percent Volatile-	pH	Percent Moisture	Percent Volatile	pH	Percent Moisture	Percent Volatile	pH
2	99.1	55.0	7.53	95.1	63.0	7.45	99.5	34.5	7.61
10	95.3	78.7	6.85	94.5	67.6	7.32	99.6	43.0	7.70
18	95.2	70.8	7.43	94.8	72.2	7.50	98.5	65.1	7.63
23	96.0	70.3	7.61	95.8	70.2	7.55	98.5	65.4	7.62
Ave.	96.4	68.7		95.1	68.2		99.0	52.0	

Digestor # 2

	1st Stage Sludge			2nd Stage Sludge			2nd Stage Supernatant		
Dec. 1969	Percent Moisture	Percent Volatile	pH	Percent Moisture	Percent Volatile	pH	Percent Moisture	Percent Volatile	pH
2	98.6	67.2	7.20	94.0	59.8	7.39	99.5	54.6	7.49
10	97.8	77.8	7.02	98.9	61.6	7.41	99.5	49.0	7.50
18	96.2	77.4	7.00	96.5	66.2	7.50	97.9	70.8	7.39
23	97.3	74.6	7.32	96.3	71.0	7.40	98.9	63.5	7.42
Ave.	97.5	76.2		96.6	64.6		98.7	59.5	

*U.S. GOVERNMENT PRINTING OFFICE:1974 882-412/44 1-3